INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

Volume 84 Chicago, May, 1926 *Number 5*

Revamping Distribution System

of a 30-year old industrial plant so as to permit changing over from locally-generated direct current to purchased alternating-current power and light service, without stopping production

By J. C. NELLEGAR

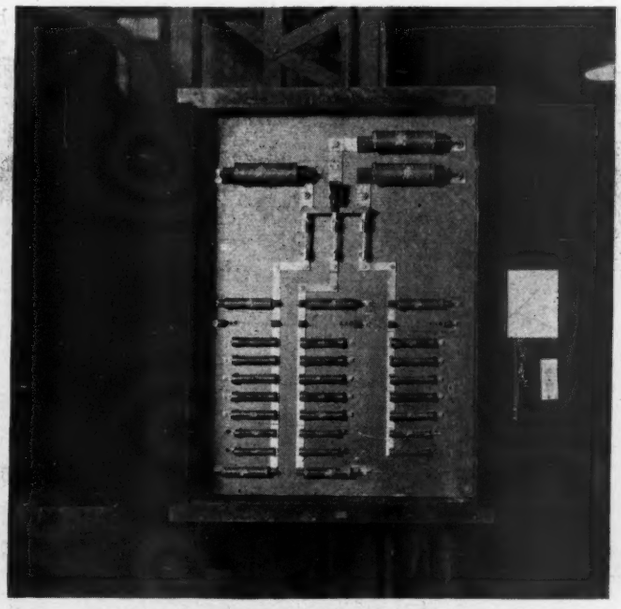
Vice-President, H. W. Caldwell & Son Co., Division of Link-Belt Co., Chicago, Ill.

OUR plant had been operating uneventfully for about thirty years until last summer when we were suddenly faced with the problem of if and how we were to continue operation. We were generating our power at 220 volts, direct current, and distributing it on a two-wire system. Steam was supplied by three 150-hp. water-tube boilers, as old as the plant. Power was generated by a collection of engines and generators which had been added on as the plant and its power load increased. In addition, the large air compressor was steam driven.

We had been aware for several years that the generating plant and distribution system were out of date and would have to be replaced soon. For this reason we had made no purchases of new motors for some time, had carried a high repair expense on the old motors, and rented a motor whenever we needed one and had no spare.

Last summer, however, one of the boilers failed and had to be taken out of service, while another boiler was down for repairs to the brickwork. The one remaining boiler could not carry the load and it was several days before the others could be put back into service. During this time, the departments ran in staggered shifts on part time and we were afraid to operate near full load capacity even when the boilers were returned to service.

In the meantime, a firm of consulting engineers, W. J. Neely Company, Chicago, Ill., were engaged to make a survey of the plant in connection with our own engineers and those of the Link-Belt Company. On the basis of this survey eight alternative recommendations were made for the solution of our problems, with the detailed estimated cost of each. Five of these recommendations, which involved the entire rebuilding of the power generating plant, could not be given serious consideration because of the urgency of the situation. The other three recommendations were based on the use of purchased power. The first plan was to use rotary converters and retain the same d.c. motors and distribution system. The second plan was similar except that motor-generator sets were to be used. These plans were rejected because many of the motors were old and would soon have to be replaced anyway. Also, the maintenance cost of direct-current motors is high and alternating current service has many more advantages in plants of this type. The third plan, which was adopted, was to purchase power, put in an entirely new distribution system, and use alternating-current motors for all except a few drives. Steam is used for heating only and is now supplied by oil-burning boilers.



Power is distributed to the various machines in each department from cabinets such as these.

Conduit is run directly from the switchboard to these cabinets. The main circuit and each individual motor circuit are protected by Buss renewable fuses. Each circuit is numbered; the machines supplied by each circuit are listed on the card on the cabinet door.

The plant consists of several buildings located closely together as may be seen from the drawing on page 205. Some of these are single-story buildings; the office building, however, is five stories high, a floor or two of which are devoted to manufacturing. The manufacture of elevating, conveying and power transmission machinery and other products required the power servicing of a foundry, machine shop, drives to rolls for making screw conveyors, a

sheet-metal shop, and other associated departments.

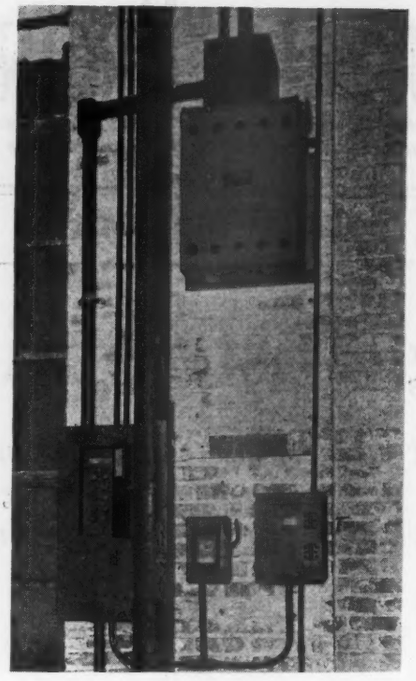
We are now operating on power which is delivered by the Commonwealth Edison Company at 12,000 volts, 60 cycles, three phase, and is stepped down by two 450-kva. General Electric transformers to 440 volts. The power goes through the 16-panel Westinghouse switchboard, shown below, and is then distributed throughout the plant as will be described later. Several direct-current motors were built into the machines, as for example on cranes, elevators, and on machine tools, and as it was not considered desirable at the present time to change them two Allis-Chalmers 100-kw., compound-wound, 250-volt, motor-generator sets driven by synchronous motors were installed to provide direct current. In addition to the present use, these motor-generator sets were necessary to supply direct current during the change-over period.

The best place to put the new switchboard, transformers, and other substation equipment was where the old boiler room stood but, as the plant had to continue in operation, the boilers could not be removed first. The procedure followed may be of interest to others who are considering a somewhat similar revamping problem.

The first consideration was to relieve the boilers by removing the demand for steam so that they could be taken out to give room for the new substation. The first piece of equipment erected was a cross-compound Worthington air compressor, driven by an Allis-Chalmers, 105-hp., synchronous motor. There was barely room to erect this in position in front of the stoker on one of the boilers. This compressor was supplied from a temporary circuit by back-feeding from a new alternating-current line which had been run into the new office building where the lighting and power load was easily changed over. This synchronous motor was excited from the old direct-current distribution system through a temporary connection. Although this is not the best operating practice, it was nesessary then.

The motor-driven air compressor took a steam-driven air compressor out of service and so enabled two boilers to carry the load. The single-set boiler was then removed.

Two Allis-Chalmers, 100-kw., 250-volt, 1,200-r.p.m., compound-wound, motor-generator sets driven by synchronous motors were next installed, along with the direct-current section and compressor-control panels of the switchboard. The direct-current plant load was then cut over to the new board by picking up, cutting, and reconnecting the old feeders into the new board. The motor-generator

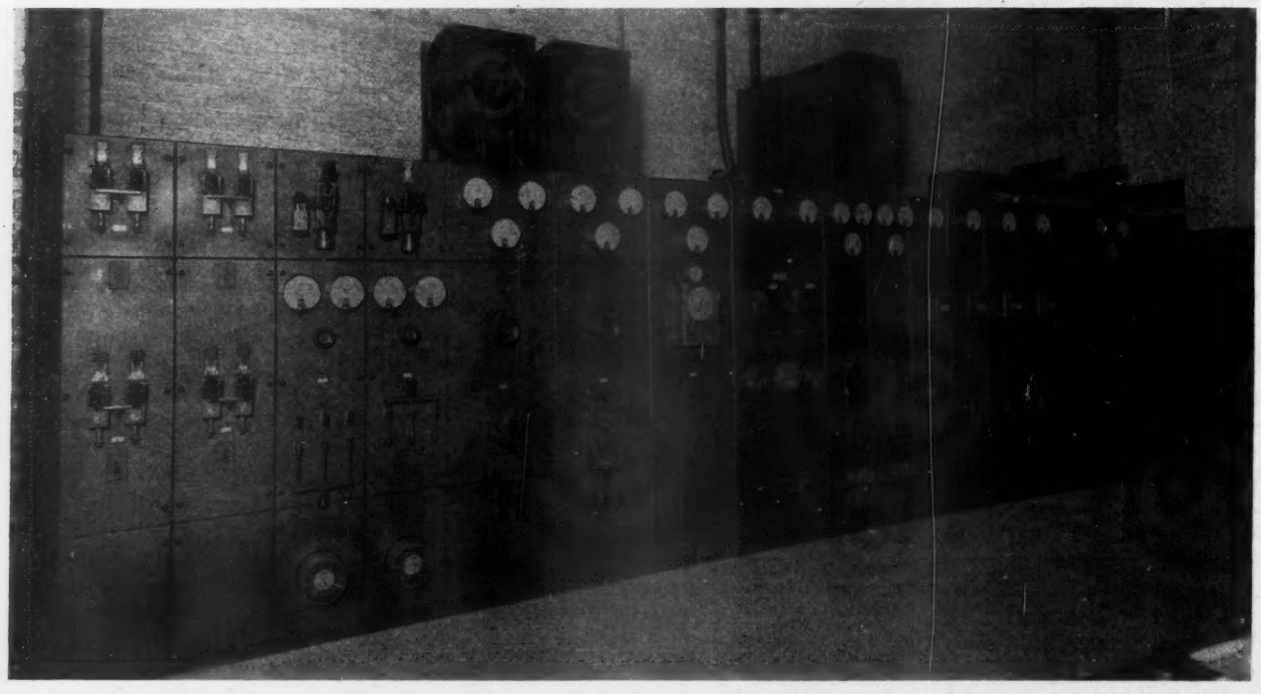


The transformers for the lighting circuits are placed at the distribution cabinets.

Current for lighting is taken from the distribution cabinets to the Packard Electric, dry-type, 440 220 110-volt transformers mounted on the wall as shown at the top of the illustration. The lighting circuits are protected by plug fuses. A Trumbull, type A, safety switch serves as a disconnect in the line. The lighting load is phase-balanced as shown in Table IV.

The distribution system at the Caldwell plant is controlled through this 16-panel switch board.

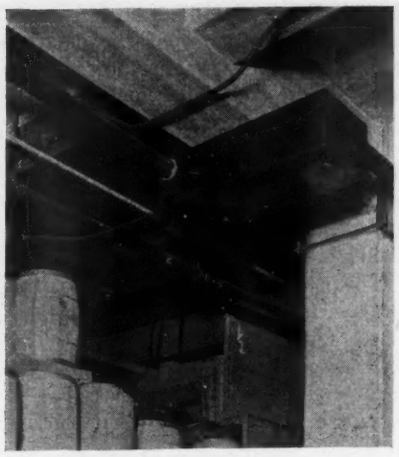
The various instruments on this board are listed in Table I. Power is delivered to the switchboard at 440 volts, 60 cycles, three phase, from two 450-kva., 12,000/440-volt transformers in the adjacent vault. The automatic Industrial Controller starter for the 20-kw. Allis-Chalmers, motor-generator exciter, which supplies the excitation for the synchronous motors on the air compressors, is on the wall at right.



sets were supplied with power from a second temporary connection.

During this time the new conduit, feeder lines, cabinets and distribution system of the plant were being installed. It was necessary to operate one engine and generator for about two weeks until enough direct-current motors had been replaced by alternating-current motors to bring the direct-current power requirements down within the capacity of the motor-generator sets. The a.c. motors, as installed, were fed from temporary connections. Also a fire pump, driven by a 100-hp., slip-ring motor was put in.

We were then able to do without steam, as this was in the early fall and we do not use steam for process work. The battery of boilers was then removed, the two 450-kva., 12,000/440-volt transformers installed permanently, and the remainder of the switchboard built in. On the first Sunday after this work was completed, all circuits were phased out and we were then ready to cut over the distribution system from the temporary to the permanent installation as convenient. I could then rest easily; until the steam plant was shut down, I spent almost as much time in the power plant as in the office. Later, another 185-hp. synchronous-motor-driven air compressor, and the oil-burning heating plant were installed.



One of the junction boxes in the 3-in. conduit line which carries three 500,000-circ. mil. cables.

In no instance was it necessary to stop production to change over, as this work was carefully planned by the engineers and the electrical contractor, the Chicago Electrical Equipment Company, Chicago, Ill. Whenever necessary, the work of cutting over was done on overtime.

So far as possible all change-overs were made by first installing the new motor and placing it in position so that it could be belted or connected by chain to the new drive before the old d.c. motor was taken out of service. In this way, the cut-overs were made quickly with a comparatively small amount of overtime and without any interruption to production. On lineshafts and most of the machine drives, the new motor was located so that it could be connected up with a Link-Belt silent chain. This makes a short-center, compact drive. The installation of chain drives greatly simplified the cut-over problem in that the old drive could be operated while the new motor was being erected in position. The change over then consisted of removing the belt and putting on the chains in another location.

All of the a.c. motors are either of the squirrel-cage induction or slip-ring type. Where variable speed was not a factor, the plant was remotored with the type FTR, 60-cycle, 440-volt, General Electric, polyphase, double squirrel-cage induction motors. These motors have a high starting torque and may be started directly across the line without the use of special starting equipment. They are controlled by General Electric type CR-7006-D5 enclosed magnetic switches from momentary-contact, start-and-stop, push-button stations. Relays provide undervoltage protection against temporary failure of voltage. All of the G. E. starters up to 25 hp. are of the same type and size for standardization. The only change necessary is in the rating of the thermal relay, to fit the horsepower of the motor. The push buttons may be placed either at the switch or at the machine. A Westinghouse enclosed, externally-operated safety switch, type WK-60 is placed in the line ahead of the magnetic switch as a disconnect. The fuses for the motor circuits are mounted in the distribution cabinets.

Table I—Instruments on Switchboard at Caldwell Plant

Panels 1 and 2 (d.c. feeders)

2 400-amp., 250-volt, two-pole, two-coil Westinghouse type CL circuit breakers.
2 single-throw, two-pole, knife switches.

Panels 3 and 4 (100-kw. compound-wound generators in motor-generator sets)

1 500-amp., 250-volt, single-pole, Westinghouse type CK inverse time element, shunt trip, circuit breaker.
1 0 to 300 volts d.c., Westinghouse style No. 293403 voltmeter.
1 0 to 600 volts d.c., Westinghouse style No. CGZ-10436 ammeter and shunt.
1 Allis-Chalmers rheostat control.
1 600-amp., 250-volt, three-pole, single-throw, type A knife switch.
1 Sangamo two-wire, 250-volt, type D-5, 500 amp. watt-hour meter with shunt.

Panels 5 and 6 (150-hp., 440-volt, three-phase, synchronous motors)

1 Westinghouse a.-c. ammeter, 8.5 amp. coil, style No. CGZ-10436; 208-amp. division marked in red.
1 Westinghouse d.c. ammeter and shunt, style No. CGZ-10436; 20-amp. division marked in red.
1 Westinghouse three-phase power factor meter, style No. 363682A.
1 Allis-Chalmers rheostat control.
1 Motor starting and running oil circuit breaker, 300-amp., Westinghouse type QF with inverse time element overload and low-voltage trip.
1 Set of 300-amp., Westinghouse disconnects.

Panels 7 and 16 (450-kva., 12,000/440-volt, three-phase, 60-cycle transformers)

1 Westinghouse a.-c. ammeter, style No. CGZ-10436.
1 Three-phase Westinghouse power-factor meter, style No. 363682A.
1 Three-phase indicating wattmeter.
1 Bristol recording voltmeter for 24-hr. circular chart. (On Panel 7.)
1 8-in. Faraday Underdome, 110-volt, a.c. bell, fed from lighting transformer. (Panel 16.)
1 1,500-amp. Westinghouse type WB2 oil circuit breaker, inverse time element, overload relays and 24-volt, d.c. shunt trip.
1 Set of 1,500-amp. Westinghouse disconnects.

Panel 8 (20-kw. exciter and Commonwealth Edison meter panel)

1 A.c. voltmeter (440-volt bus), Westinghouse style No. CGZ-10436.
1 D.c. voltmeter, 0 to 300 volts, Westinghouse style 293403B.
1 Allis-Chalmers rheostat control.
1 100-amp., 250-volt, two-pole, double-throw type A knife switch.
2 G. E. polyphase watt-hour meters type O-6, Commonwealth Edison Co. metering.
2 G. E. demand meters.
1 G. E. instantaneous overload relay, type Q-6.

Panels 9 and 10 (105-hp. and 185-hp. synchronous motors on compressors)

Metering same as on panels 5 and 6.
1 Set of hand-operated Westinghouse disconnects for oil circuit breakers, style No. 296782:
200-amp. disconnect for panel 9.
300-amp. disconnect for panel 10.

Panels 11, 12, 13 and 14 (a.c. feeders)

1 Westinghouse a.c., 500-amp. ammeter, style No. 363836A.
Panel 14, 700-amp. ammeter.
1 Westinghouse type OA polyphase watt-hour meter.
1 Westinghouse 400-amp. oil circuit breaker, inverse time element overload relays.
1 Set of 400-amp. disconnects.
Panel 14 has 600-amp. circuit breakers and disconnects.

Panel 15 (a.c. feeder)

Blank, with 600-amp. capacity for future expansion.

Table II—Partial List of Materials Used

16,880 ft.	½-in. Buckeye conduit
6,620 ft.	¾-in. Buckeye conduit
4,000 ft.	1 -in. Buckeye conduit
3,130 ft.	1¼-in. Buckeye conduit
870 ft.	1½-in. Buckeye conduit
940 ft.	2 -in. Buckeye conduit
630 ft.	2½-in. Buckeye conduit
1,620 ft.	3 -in. Buckeye conduit
380 ft.	3½-in. Buckeye conduit
	Habirshaw wire
58,125 ft.	No. 14 R.C.S.B.
8,750 ft.	No. 12 R.C.S.B.
6,875 ft.	No. 10 R.C.S.B.
5,000 ft.	No. 8 R.C.S.B.
	Stranded
3,260 ft.	No. 6 R.C.S.B.
1,250 ft.	No. 4 R.C.S.B.
625 ft.	No. 3 R.C.S.B.
625 ft.	No. 2 R.C.S.B.
2,050 ft.	No. 1 R.C.S.B.
	Cable
800 ft.	No. 4/0 R.C.D.B.
492 ft.	No. 3/0 R.C.D.B.
1,250 ft.	No. 2/0 R.C.D.B.
398 ft.	No. 1/0 R.C.D.B.
142 ft.	700,000 circ. mil
3,624 ft.	500,000 circ. mil
1,125 ft.	400,000 circ. mil
	R.C.L.C. cable
785 ft.	500,000 circ. mil
510 ft.	400,000 circ. mil
500 ft.	350,000 circ. mil
350	Benjamin R.L.M. reflectors equipped with lamps furnished by Peerless-Brilliant Lamp Division
300	Bryant switches and receptacles
10	Packard dry-type transformers, 440-volt, single-phase primary; 110/220-volt secondary
600	Miscellaneous Unilet fittings
612	Miscellaneous 600-volt Buss renewable fuses
14	Power cabinets and panels, 4 to 12 circuits each
15	Wall-mounted lighting cabinets and panels, 8 to 20 circuits each
56	Special pull boxes
126	Type A, two- and three-pole 220/440-volt fused and unfused safety switches

All slip-ring motors are General Electric type MT, 440 volts, three phase, 60 cycles. These are controlled by G. E. type CR-3204-1500A secondary drum switches with interlocked primary contacts, G. E. type 7006 D5.

The distribution system centers around the switchboard. This is a 16-panel (including a spare panel) Westinghouse switchboard constructed of Johns-Manville Ebony Asbestos Wood in black marine finish. The framework is of angle iron and the panels rest on a channel-iron base, set in the concrete floor. In addition to the metering of the incoming power, each distribution panel is provided with a Westinghouse recording watt-hour meter as well as the necessary indicating volt- and ammeters. This gives the power consumption in all departments and permits charging each department with its proper power load. In some instances, two or more departments are supplied from the same panel, and so have one watt-hour meter in common. In such cases other meters are placed at the distribution cabinets in one or more of the departments. In this way the power consumption in each department may be obtained by subtraction. The power consumption also indicates the activity of a department. The instruments on the different panels of the main switchboard are listed in Table I.

The synchronous motors on the 100-kw. motor-generator sets are excited from their generators. The excitation for the synchronous motors on the air compressors is provided by a special 20-kw., motor-generator set located in the substation, but not shown in any of the illustrations. In addition, a double-throw, two-pole switch, shown on the lower portion of panel 8, permits connection to the d.c. bus fed from the 100-kw. motor-generator sets to obtain 250-volt excitation for the compressor motors in an emergency. The synchronous motors on the air compressors are equipped for automatic starting. This is done through a standard oil switch on the panel which is connected to a Westinghouse frequency relay that automatically closes the field circuit at a predetermined speed value.

All circuit breakers on the switchboard are equipped with an automatic alarm switch and a manual cutout to open the alarm circuit when the circuit breaker is left open. In addition, a signal system is provided which indicates any difficulty on the incoming 12,000-volt power lines. The 12,000-volt line switches and the 12,000-volt transformer switches are equipped with relays which open these switches in case of trouble. The line and transformer switches are equipped with contactors which operate drops in an annunciator and also blow a signal horn, both of which are located on the main switchboard. In case a high-voltage line or transformer switch opens, the operator's attention will be attracted by the horn. The switch which has opened is indicated by the drop on the annunciator. The trouble is then reported to the load dispatcher of the power company who will take immediate steps to correct the difficulty.

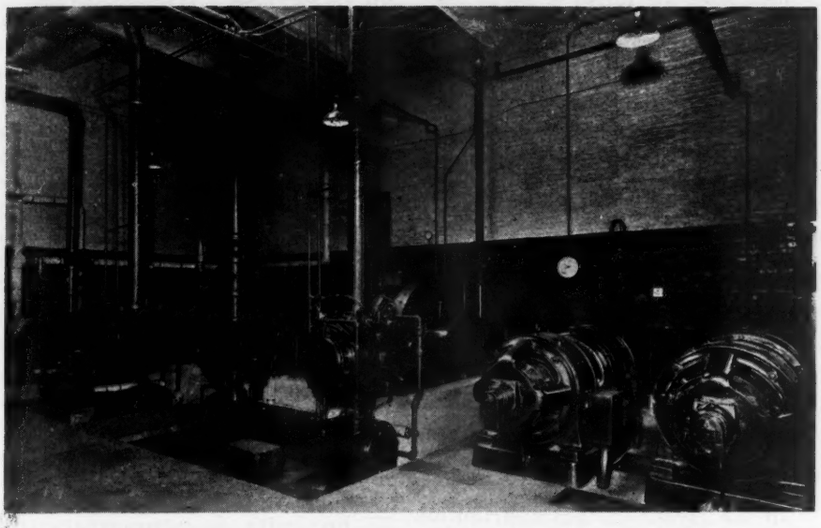
Every precaution has been taken to prevent interruption of the fire-pump service. To this end, the 100-hp. fire-pump motor has two sources of supply, one from each of the power transformer secondaries. Feeders are run directly from each transformer secondary to a three-pole, double-throw knife switch which is placed on the wall of the substation. The switch blades are connected to the fire-pump motor control in the pump room. The light and power supply for the substation and boiler room is controlled by another three-pole, double-throw switch in the same manner as is the pump-room service. The two switches, however, are located in the

Table III—List of A. C. Motors Used

Rated Hp.	Machine Driven	Type of Drive
	Warehouse	
5	Lineshaft	Belt
5	Lineshaft	Belt
15	Lineshaft	Chain
5	Lineshaft	Chain
10	Elevator	Belt
10	Elevator	Belt
	Foundry	
1	Dust arrester	Gear
15*	Heating fan	Chain
7.5	Exhaust fan	Chain
10	Lineshaft	Chain
20	Tumbler	Gear
15	Grinder	Gear
15	Grinder	Chain
7.5	Lineshaft	Chain
5	Lineshaft	Chain
50*	Cupola blower	Chain
15	Cupola blower	Belt
0.5	Lineshaft	Belt
5	Tumbler	Chain
	Sheet Metal Shop	
5	Punch press	Gear
15	Lineshaft	Chain
15	Lineshaft	Chain
2	Forge blowers	Chain
	Machine Shop	
10	Car puller	Built in
7.5	Press	Gear
15*	Heating fan	Chain
5	Drill press	Chain
10	Radial drill	Chain
10	Milling machine	Belt
15	Lineshaft	Chain
7.5	Lineshaft	Chain
7.5	Keyseater	Gear
20	Radial drill	Chain
20	Planer	Gear
15	Lineshaft	Chain
1	Power saw	Belt
15*	Heating fan	Chain
15	Pulley grinder	Belt
25	Pulley grinder	Gear
15	Lineshaft	Chain
10	Lineshaft	Chain
10	Boring mill	Belt
7.5	Lineshaft	Chain
20	Boring mill	Chain
10	Elevator	Belt
15	Lineshaft	Chain
5	Lathe	Belt
20	Lineshaft	Chain
	Conveyor Shop	
15*	Heating fan	Chain
3	Forge blower	Built in
40*	Hot press roll	Built in
7.5	Hammer	Belt
10	Lineshaft	Belt
50*	Hot roll	Built in
15	Fan	Belt
10*	Cold roll	Chain
75*	Cold roll	Chain
10	Lineshaft	Belt
15	Lineshaft	Belt
10	Lineshaft	Belt
5	Lineshaft	Belt
7.5	Punch press	Belt
20	Punch press	Belt
10	Lineshaft	Belt
0.5	Exhaust fan	Built in

All motors are 440-volt, three-phase, 60-cycle General Electric type FTR, double-squirrel-cage induction motors, except those marked in this table with an asterisk (*).

* Type MT, General Electric, 440-volt, three-phase, 60-cycle, slip-ring motors.



This equipment in the substation is placed opposite the switchboard.

Either of the two Allis-Chalmers 100-kw. motor-generator sets is capable of supplying enough direct current to operate all of the d. c. equipment which still remains in the plant. These sets, however, were required to supply direct current during the change-over, before all of the new a. c. equipment had been installed. The two Worthington, two-stage, cross-connected air compressors are driven by 105-hp (center) and 185-hp. (left) Allis-Chalmers, 440-volt, 60-cycle, three-phase, synchronous motors excited from a 20-kw. m. g. set.

substation at a considerable distance apart and on different walls of the room, so that there will be less likelihood of confusing them.

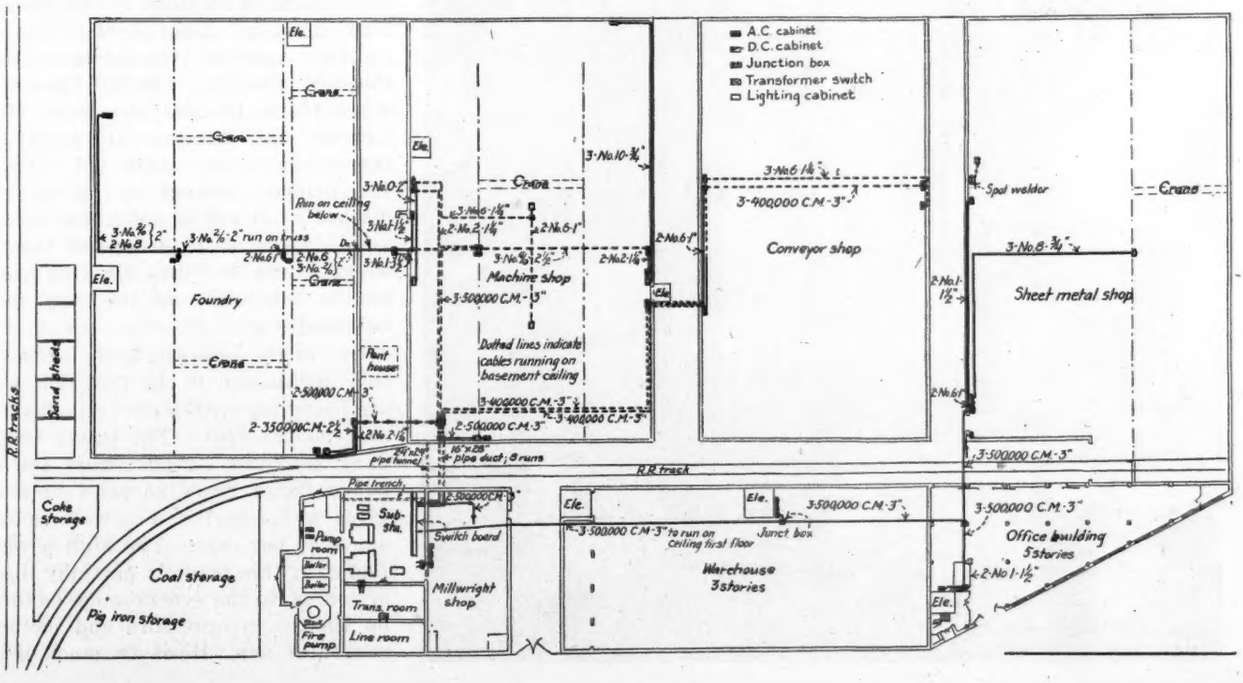
The double-throw switches for each service are connected so that with both switches "up" they connect to the secondary of the same power transformer. Similarly, if both switches are "down," the connection is made to the other power transformer secondary. When both power transformers are in service, these switches can be thrown either both "up" or both "down," or one "up" and one "down." It is desirable, however, that both of them always be thrown in the same direction. Why this is so is probably best shown by analyzing the operating conditions. Suppose, for example, that both switches are thrown "up," that is, taking power from transformer No. 1. Assume that transformer No. 1 fails and is automatically taken out of service by the protective relays; the failure of transformer No. 1 would put out the substation lights and the operator would then transfer the station light and power to transformer No. 2 by throwing the service switch "down." The next move would be to throw the fire-pump service switch "down," or onto transformer No. 2, and thus restore the fire-pump service.

If the substation were operating with both switches "down," or on transformer No. 2, and transformer No. 2 should fail, the above cycle of operations would be repeated and service restored by throwing both switches "up" which would transfer the load to transformer No. 1.

The objection to operating with one switch "up" and the other "down" is as follows: Suppose the substation service switch is thrown "up," or on transformer No. 1 and the fire-pump service switch is "down," on transformer No. 2. In case transformer No. 2 fails and is automatically taken out of service, the substation light and power supply would not be interrupted because it is connected to transformer No. 1. The signal horn would blow and the operator would be busy notifying the load dispatcher and looking after the load on the switchboard. This presents the possibility of forgetting to throw the fire-pump service switch "up," and thus leave the plant without fire protection.

Power is distributed from the switchboard to the various departments, as already mentioned, by separate feeders in conduits extending from the various panels as indi-

This shows the layout of the distribution system and the location of the power and lighting cabinets in the various departments.



cated. The feeders go down from the back of the switchboard into an 18-in. by 18-in. trench in the concrete floor, with a slate cover. In this trench there are three 3-in. conduits, each of which contains three 500,000-circ. mil, Habirshaw rubber-covered cables, and three 3-in. conduits, each containing three 400,000-circ. mil r.c. cables for the a.c. distribution system. Direct current is also distributed from the switchboard through two 3-in. conduits, each containing two 500,000-circ. mil, r.c. cables.

All but one feeder line crosses underneath the railroad tracks in a 16-in. by 28-in. pipe duct underground, which extends into the basement of the machine shop. The layout of the distribution system between the switchboard and the department cabinets is shown in the accompanying drawing on page 205. The dotted lines indicate that the conduit runs are carried underneath the basement floor. The solid lines indicate conduit runs on the walls or ceilings. The locations of the various junction boxes and cabinets are also indicated.

Starting equipment and control for two of the motors.

All constant-speed motors are General Electric type FTR, 60-cycle 440-volt, polyphase, double-squirrel-cage induction motors which may be started directly across the line. The motors are controlled by start-and-stop push buttons (one may be seen on the side of the magnetic switch) which operate through General Electric type CR-7006-D5 enclosed magnetic switches. The safety switch placed above the magnetic switch is a Westinghouse type WK-60 which serves as a disconnect. From the control equipment the motor feeders are carried in conduit underneath the floor and brought up to the motor as shown, on the radial drill at the left, through flexible steel conduit. Many of the motors in this plant are connected to the driven machine by Link-Belt silent-chain drives.

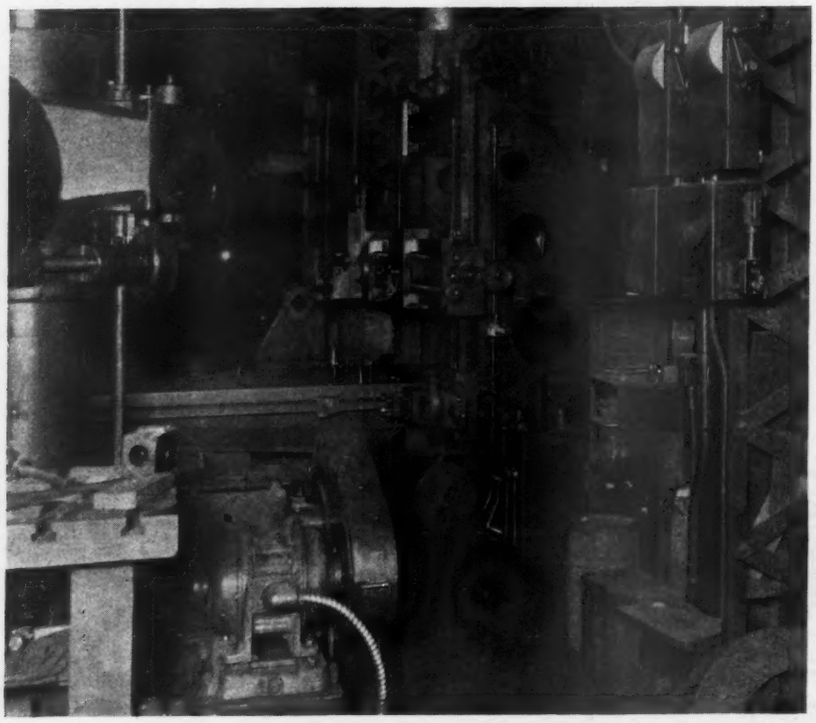


Table IV—Phase Balancing of Lighting Load

Load	Service	Phase
37.5 kva.	Office building—Lighting	C-A
37.5 kva.	Sheet-metal shop—Welders	B-C
15 kva.	Sheet-metal shop—Lighting	A-B
15 kva.	Warehouse—Lighting	A-B
10 kva.	Foundry—Lighting	A-B
15 kva.	Foundry—Lighting	B-C
25 kva.	Machine shop—Lighting	C-A
25 kva.	Machine shop—Lighting	A-B
15 kva.	Conveyor shop—Lighting	B-C
5 kva.	Substation—Lighting	C-A

In the layout of this distribution system the substation and main feeder lines were designed for an ultimate capacity of practically twice our present requirements, which are now supplied by the two 450-kva. main transformers. The incoming line room and transformer vault were built to hold two 1,000-kva. transformers and the switchboard and distribution lines will care for the load when the time comes. By that time, the feeders between the distribution cabinets and the various machines will most likely require relocation and any necessary increases in the size of wire in the conduits from the cabinets to the machines can be made at that time. However, in no case is the wiring figured so closely that some increased load cannot be taken care of now.

Wherever possible, the conduit is exposed and supported by pipe straps on all runs. In all cases, where possible, the conduit was placed in long runs with the necessary pull boxes installed in the runs to facilitate pulling in the wire. One of the steel distribution cabinets is shown in an accompanying illustration. The amount of wire, conduit, fittings and other material and equipment used on the job is given in Table II. The total cost, including installation, of the equipment and distribution system was approximately $150,000.

There are in all about 85 alternating-current motors in this plant, varying in rating from ¼ hp. to 75 hp., with an aggregate rating of 950 hp. A partial list of the motors is given in Table III. This total does not include the four synchronous motors on the motor-generator sets or connected to the compressors and the 100-hp. fire-pump motor.

As stated before, it was considered desirable to continue the use of direct-current motors totaling about 300 hp. This was particularly true of the crane and elevator service where the motors are built into the equipment. In the case of the belted elevators, however, the d.c. motors were removed and high-resistance, squirrel-cage motors installed in their place.

Current for lighting the departments is stepped down by a 2:1 ratio transformer to 220/110 volts. In this way, the lighting load of each department is included in the power load of that department. These lighting service transformers are Packard Electric, 440/220/110-volt, single-phase, 60-cycle, dry type. To balance the system, all lighting transformers are connected across the primary phases as shown in Table IV. It will be noted that these are balanced off in groups of three, which leaves the 5-kva. lighting load in the substation as the only unbalanced load.

One of the interesting features of this installation is the fact that we are operating with a power factor of over 90 per cent. The power company penalizes its customers for a power factor below 85 per cent and gives a bonus for a power factor above 85 per cent. The high power factor in this plant is partially due, of course, to the synchronous motors on the air compressors and motor-generator sets. However, much of it

is due to the careful selection of the rating of the motors installed on the various drives. Ordinarily, the load on any motor may be obtained by connecting the proper indicating or recording instruments in the circuit. When studies were made on the old installation, we were operating at an absolute minimum of power requirements because of the danger which might result from loading up the steam plant. After making some tests it was soon seen that it would be impossible to get any accurate results in this way. It then became necessary to select the motors for the different drives largely on the basis of judgment and the experience of our operating engineer as to whether or not the old direct-current motor had been heavily loaded.

The induction motors selected will operate at a power factor of about 85 per cent when fully loaded. To take advantage of this high power factor when loaded, we selected for each drive a motor of such rating that it would be well loaded under general operating conditions, even though it might be slightly overloaded under maximum operating conditions, which would seldom last for a long period. Because the motors are well loaded they operate at a high power factor which, with the corrective effect of the synchronous motors, enables us to operate at 90 to 94 per cent power factor.

With the exception of a few minor changes, the work is all completed. One of the big savings we have noted is the drop in the maintenance expense from about $300 a month, which was the case when the old motors were in use, down to practically nothing. Perhaps the most important result, although it cannot be measured in any monetary value, is the relief which comes with the knowledge that there will be but little likelihood of interruptions in production through power failure.

Construction of Tracing Desk Lighted from Beneath

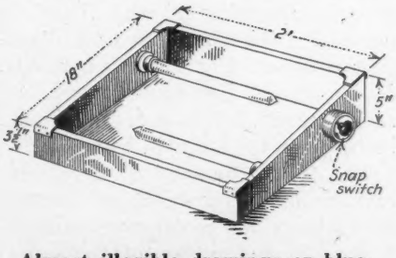
IT IS often necessary to trace a drawing or blueprint the lines of which, when covered with tracing paper or cloth, are almost invisible. Holding a drawing against the window does not tend toward accuracy or neatness. Often it is almost necessary to redraw to get lines heavy enough to trace.

This difficulty has been overcome in our case by the use of the specially-lighted, glass-topped tracing desk shown in the accompanying sketch. Most gratifying results have been obtained and I thought perhaps others might have occasion to use it, as the desk is not only inexpensive, but easily made.

This desk consists of a wooden box, without top or bottom, made in the shape and dimensions shown on the drawing. The corners may be nailed, screwed or joined as desired. Wood at least ½ in. thick, and preferably heavier, should be used. Before fastening the corners together the top should be rabbeted to a depth equal to the thickness of the glass. Heavy window glass may be used, although plate glass is preferable.

The glass may be held in place with small, metal corner pieces, such as may be procured at any hardware store. These should be thin so as to interfere as little as possible with the drawing instruments. The left edge of the box may be trued up for the T-square. The lights and sockets are placed on the inside as shown and wired in parallel to the switch. The best distribution of the light is obtained by using the long type of frosted Mazda lamps, which are about 12 in. long by 1 in. in diameter. These can usually be obtained from local lamp dealers. The material required, in addition to the box and glass are two lamps, two porcelain sockets, a snap switch, and 8 or 10 ft. of two-strand flexible cord, fitted with a plug.

It is not necessary to place a bottom in the box although, if this desk is to be moved around much, it would probably be safer to do so as then there would be no possibility of placing the desk down on some unnoticed object and breaking the lamps. Better results may be obtained by painting the inside of the box white and, if no bottom is used, placing it on a sheet of white paper.



Almost illegible drawings or blueprints may be easily traced by the use of this glass-topped desk, which is lighted from beneath.

The glass is set flush with the top of the desk by cutting a rabbet (not shown in the drawing) in the top edge of the side pieces. If the drawing desk is to be made larger a plate glass top will be necessary. Also, it would then be well to add more lamps and fasten them alternately to the top and bottom instead of the sides.

Bedford, Ind. AUGUST JEFFERS.

Comment on "Power Drive Equipment for Air Compressors"

ON PAGE 15 of the January issue, in an article entitled "Power Drive Equipment for Air Compressors" by Gordon Fox, the following statement was made: "It is quite feasible to store a large supply of air in a receiver, the latter serving primarily to prevent frequent starting and stopping of the compressor due to leakage in connection with a piping system of small volume."

This sentence should have read, "It is *not* feasible to store a large supply of air in a receiver, the latter serving primarily to prevent too frequent starting and stopping of the compressor *caused by* leakage in connection with a piping system of small volume."—EDITORS.

Simple Kinks for Making Tight Joints

WHERE a plastic is needed for making a tight joint in a gasoline line, soap may be used. It has one great advantage in that it is available anywhere at all hours.

For making an oil-tight joint, use glycerine and litharge (oxide of lead). Mix this into a paste of the consistency of thick cream and use it between the metal surfaces or between metal and glass. A valuable property of this mixture is its elasticity for it may be put between surfaces that are subject to bending and it will not crack; this makes it very useful on parts that are subject to serious vibration.

Inserting rubber gaskets in recesses or pockets that are below the surface requires doubling them up so that they may be crowded through a narrow opening. When it is difficult to get these gaskets in place, much can be done by lubricating them with thick soapy water using, preferably, glycerine soap.

DONALD A. HAMPSON.

Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

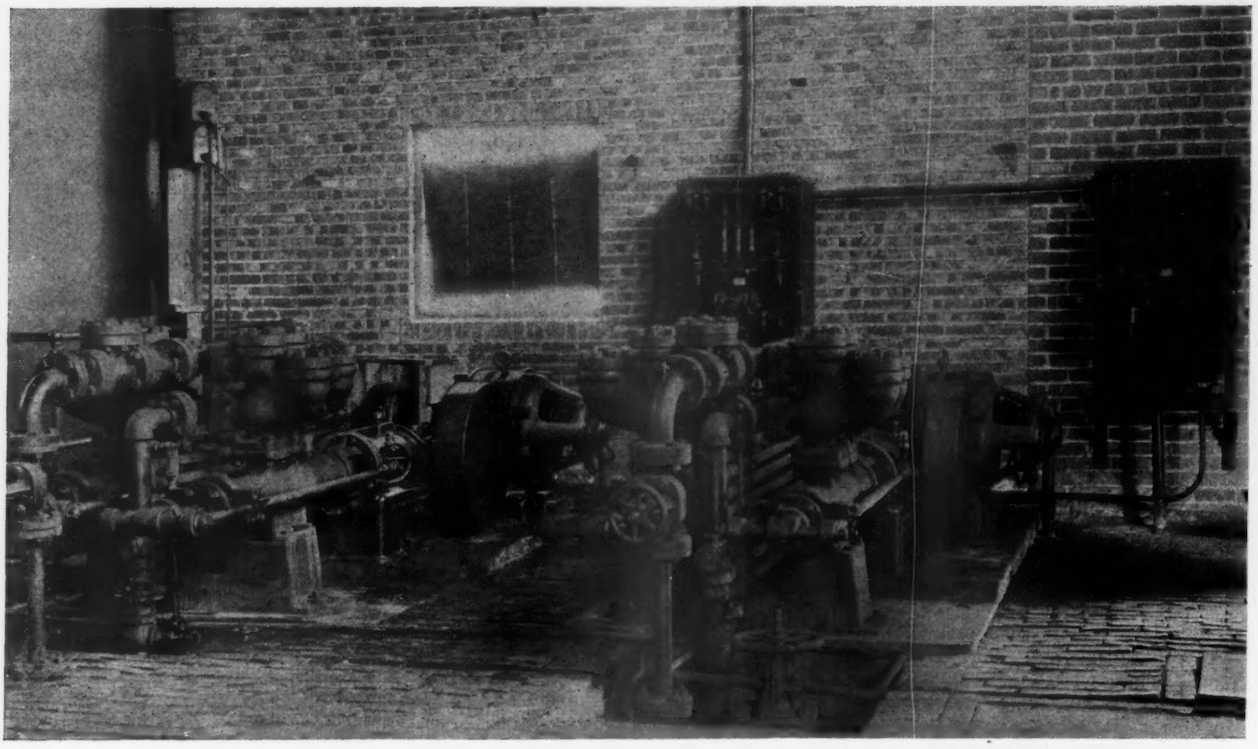


Fig. 1—These wound-rotor motors drive reciprocating pumps in a steel mill.

The two duplex, double-acting pumps deliver a pressure of 1,000 lb. per sq.in. to an accumulator shown at the extreme left. This high pressure is used as a power transmitting medium for certain steel mill equipment. Cutler-Hammer automatic control panels start and stop the motors, through the action of a float or limit switch shown at the left, mounted adjacent to the accumulator. Two gear reductions are used to get the proper speed.

Power Drive Equipment for Industrial Pumps

together with a discussion of their operating characteristics which affect the selection of the motor, control, and drive connection

By GORDON FOX
Electrical Engineer, Freyn Engineering Company, Chicago, Ill.

PUMPING of liquids is one of the most commonplace operations. The essence of pumping is power. It is said that more power is used for driving pumps than for any other kind of machine. Inasmuch as a very large number of pumps are motor-driven the requirements of pump drives are worthy of particular attention.

The two more common types are reciprocating pumps and centrifugal pumps. Rotary displacement pumps are less commonly used. These three types differ widely in many respects.

Reciprocating pumps work on the displacement principle. The action is positive, a fairly definite amount of liquid being displaced at each stroke of the plunger. These pumps are termed simplex, duplex, triplex, or quadruplex, according to the number of cylinders and pistons or plungers. In all pumps having more than one plunger the cranks are angularly displaced, which tends to equalize the liquid flow and power requirement. Pumps are termed single-acting if they displace liquid during one direction of travel only and are double-acting if the liquid is moved by the piston in each direction of travel. Fig. 1 shows a duplex, double-acting, high-pressure reciprocating pump, while a triplex pump installation is shown in Fig. 5.

The torque demand of a reciprocating pump is subject to periodic fluctuations due to varying crank effort. The magnitude of the pulsations is influenced by the number of cylinders. A flywheel is generally required to assist in smoothing out the torque demand.

Reciprocating pumps are normally slow-speed machines, the crankshafts usually running about 50 r.p.m. A gear reduction of about 4:1 is commonly inserted between the crankshaft and driven shift, which thus revolves about 200 r.p.m., as shown in Figs. 1 and 5. The motor may be connected to this driven shaft through a belt, gear, or silent-chain drive. In some instances synchronous motors are coupled directly to this shaft.

Reciprocating pumps have, in general, the following advantages: (1) Their efficiency, at high heads, is usually higher than that of centrifugal pumps. (2) They may be employed for higher heads than are obtainable with centrifugal pumps. (3) They are more simple where small quantities of liquid are required at high heads. (4) They give positive delivery and will usually start without priming.

The capacity of a reciprocating pump in gallons per minute may be found by the formula,

$Q=0.0034\times N\times d^2\times L\times K$, where

Q=capacity in gal. per min.
N=effective strokes per min.
d=piston diameter, in inches.
L=length of stroke in inches.

K=a constant, a measure of the slip or leakage. It varies from 0.7 to 0.97 depending on conditions. An average value of K is 0.95.

The power required by any pump may be expressed by the formula, $Hp.=(Q\times P)\div(1713\times E)$, or $(Q\times H)\div(3960\times E)$, where

Q=delivery in gal. per min.

P=pressure in lb. per sq. in.

H=total head in feet.

E=pump efficiency.

Average values of efficiencies for reciprocating pumps are given in Table I.

Very small pumps have lower efficiencies, as low as 25 per cent.

Reciprocating pumps displace a fairly definite volume of liquid at each stroke. The following conditions, therefore, apply to pumps of this type: (1) Reduction of head affects the volume or quantity delivered very little. (2) Reduction of head affects power required in direct proportion to the reduction. (3) Variation in speed when the pump is operating against constant head, causes the volume to vary in direct proportion. (4) Variation in speed, when operating against constant head, causes the power required to vary in direct proportion. The torque is fixed if head is constant.

A rotary pump displaces a definite quantity of fluid at each revolution of the pump rotor. This type of pump works under variable heads with a constant rate of discharge so long as the speed remains constant. Hence, if the speed is constant, the power required is directly proportional to the total head; or if the head is constant and the speed changed the power and rate of discharge vary directly as the speed.

The power requirement of the rotary pump is similar in all respects to that of the reciprocating pump and the power formula given on this page may be used. The relations of torque, power, speed, and volume are the same as with reciprocating pumps.

The rotary pump is similar to the positive displacement rotary blower. Quite commonly the rotors have three lobes. This type of pump is used only in small sizes and for moderate heads. For this service it enjoys the advantages of simplicity and absence of valves and packing. The pumping action of the rotary pump resembles that of the multiple cylinder reciprocating pump in its positive action, definite displacement, and somewhat pulsating delivery and torque. The speeds of rotary pumps are usually so low that motors of ordinary speed must be geared or belted to the pump shaft. Fig. 6 shows an installation of rotary pumps in which speed reducers are used to obtain the desired speed.

SELECTION of motors and auxiliary equipment for industrial applications is the subject of this series of articles by Gordon Fox. Previous articles of this series have appeared in the January and March issues. The accompanying article discusses the characteristics of reciprocating, rotary and centrifugal pumps, with reference to the application of motors to each type. A succeeding article will go into greater detail regarding the motors, control and auxiliary equipment best suited for pump applications.

Single-stage centrifugal pumps having a volute casing are used for low-head service up to about 200 ft. Multi-stage pumps are used for higher heads. Pumps of the latter type may be operated in series to develop heads up to 2,000 ft. Single-stage centrifugal pumps are illustrated in Fig. 8 while Fig. 7 shows an installation of multi-stage pumps.

Centrifugal pumps for moderate and high heads, and all multi-stage pumps, are inherently high-speed devices. Low-head pumps, particularly for large capacities, normally operate at moderate speeds and sometimes at low speeds. The tendency in general is toward high speeds as the impeller diameter and pump size are reduced thereby and the best efficiencies are usually attained. In the multi-stage pump the number of stages required may be less at a higher speed.

Centrifugal pumps have the following general advantages over other types of pumps:

(1) Simplicity, with minimum number of wearing parts.

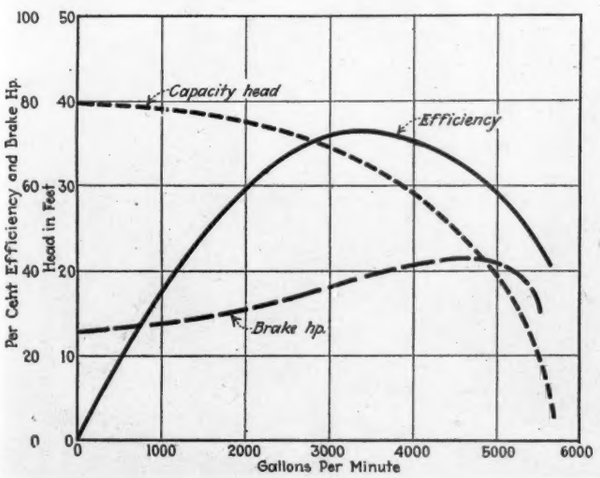
(2) Due to the high speeds used, they are relatively small, compact, and low in first cost.

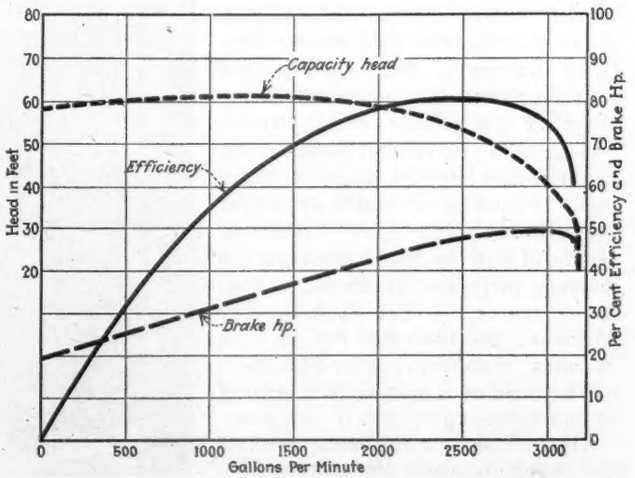
(3) They will handle dirty water, sewage, and water containing solids up to 40 per cent if designed especially for this requirement.

(4) They will not develop pressure beyond a predetermined value, in case flow is shut off. They may, therefore, be used on closed hydraulic systems to maintain a fixed pressure, churning during idle periods.

Figs. 2 and 3—Power required by centrifugal pump running at constant speed.

The power input required by a given pump varies with the number of gallons per minute delivered by the pump. The latter in turn depends upon the head pumped against. These relations are shown in the brake horsepower and capacity curves in both graphs. Fig. 2 on the left is for a pump having a steep capacity-head characteristic, while Fig. 3 is for a pump having a flat capacity-head characteristic.





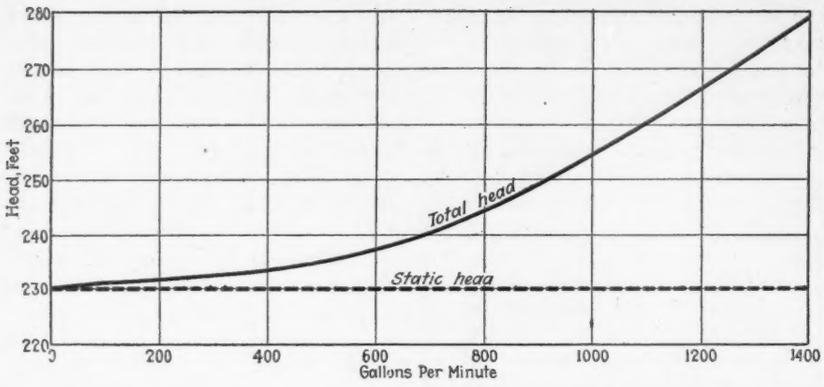


Fig. 4—This curve shows the total head required for various deliveries in gal. per min. on a given system.

The head of a system consists of the static head composed of suction lift and discharge head, the total of which is constant for a given system, as shown in the diagram. Superimposed on this is the friction head and velocity head which vary with the flow of liquid. The head delivered by a pump must equal the system head for the particular capacity or delivery required in order to maintain a condition of equilibrium.

(5) They deliver a steady flow at uniform pressure.

(6) They enable the use of high-speed, efficient motors of low first cost.

(7) They are more efficient than reciprocating pumps for low-head service.

(8) They will handle hot water to advantage.

The capacity of a centrifugal pump depends largely upon design details and cannot be determined by a general formula but must be obtained from the pump manufacturer's rating or curves.

The power required to drive a centrifugal pump can be determined by formulas given for reciprocating pumps on page 209.

Table II on page 211 gives approximate average values of efficiency for various centrifugal pumps when pumping clean water. Pumps having a high suction lift, such as condenser removal pumps and condensate pumps, have slightly lower efficiencies than those given in Table II.

As a general rule, head, speed, and power relations may be considered only by means of characteristic curves. The characteristic curves of a given pump show the efficiency, power input, and head developed, plotted as ordinates against volume or gal. per min. as abscissas. Fig. 2 shows the characteristic curves of a pump having steep capacity-head or *Q-H characteristic*, while Fig. 3 shows the characteristic curves of a pump having a flat capacity-head characteristic. The principal factor affecting the capacity-head characteristic of a centrifugal pump is the angle of the impeller blades at their tips. If the tips are radial or curved forward, in the direction of rotation, the head will be maintained as the delivery increases, as shown in Fig. 3. However, if the blades curve backward, the head will fall off with increase of delivery, as in Fig. 2.

The head of a system is composed of the following:

(1) Suction lift or intake head if the supply is above the pump. This may be somewhat variable in amount.

(2) Discharge head or elevation of the water column in the system above the pump. This may vary between limits.

The combination of (1) and (2) is commonly termed the static head.

(3) Friction head, due to friction in pipes, fittings and valves. This is determined from tables of losses in pipe lines and fittings and varies with the volume, being proportional to the square of the volume and velocity.

(4) Velocity head$=V^2 \div 64.4$, where V is discharge velocity in ft. per sec. at discharge nozzle of pump.

The head of a system is commonly represented by a curve, as shown in Fig. 4, which shows the static head with no flow and the head increasing with the flow. The friction head in piping must not be neglected, lest the volume delivered by a centrifugal pump fall short of that desired or the motor driving a reciprocating pump be overloaded. The head developed by a pump must equal the head of the system on which it is working, to give a condition of equilibrium. Hence, if we superimpose the curve of system head upon the curve of the pump head, the point of intersection represents the condition of equilibrium and the corresponding volume gives the flow which will occur under the given condition. The corresponding horsepower also may be read from the power curve.

The operating characteristics of centrifugal pumps differ radically from those of reciprocating pumps. The characteristics of centrifugal pumps follow these general rules:

(1) With constant speed, the volume will vary inversely as some function of the head, depending on the pump characteristic. Reduction of head causes great increase in volume delivered if the pump has a flat capacity-head curve and relatively small increase in volume if the pump has a steep capacity-head curve.

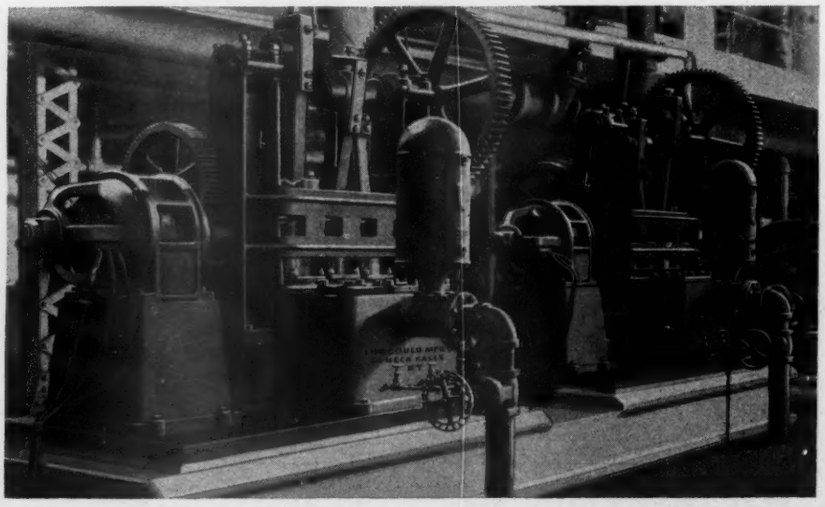
(2) With constant head applied, the volume will vary as some function of the pump speed depending on the pump characteristic. Variation in speed causes relatively great change in volume if the pump has a flat capacity-head curve and less change in volume if the pump has a steep capacity-head curve. If there is no static head, the volume varies directly with the speed.

(3) The head developed by a centrifugal pump is proportional to the square of its speed. The volume varies as the speed, if there is no static head. If there is a static head, the relation is not directly proportional.

(4) The power required by a centrifugal pump is a function of its vol-

Fig. 5—Due to the heavy starting torque required, wound-rotor motors were selected for these triplex pumps.

These Gould pumps are installed at Central Mercedita of Yabucas, a sugar mill in Porto Rico.



ume and head and will vary materially as these vary. If there is no static head, the power required varies as the cube of the speed.

Although the centrifugal pump is similar in principle to the centrifugal fan, its performance is materially affected by the presence of static head which is independent of volume. The system head of a fan commonly varies as the square of the velocity. The system head of a pump commonly comprises the more or less fixed static head and the friction and discharge heads. The latter two components vary with the square of the velocity. If there is no static head, the pump and the fan are comparable.

It is universally true, within limits, that the capacity of a centrifugal pump varies directly with the speed and that the head developed varies with the square of the speed. When the system head is comprised partially of static head, however, the intersection or operating balance between pump head and system head occurs at a different point on the pump characteristic when the speed is changed, so that the actual resulting volume and head are not directly calculable.

To determine the effect of any changed conditions, new curves should be plotted and the corresponding balance point determined. If a change is made in the system head by throttling the discharge, the friction head will be increased so that the system head curve will bend more rapidly and a condition of equilibrium will occur at a lower volume and lesser power input. If the change is in the static head, as by a change in standpipe level, the system head curve will have its original curvature but will be higher or lower an amount corresponding to the change in static head. If the static head will fluctuate between limits the two system head curves may be plotted corresponding to these limits and the corresponding points of balance limiting the operating range determined.

Table I—Average Efficiency of Reciprocating Pumps

Head Pumped Against in Ft.	Efficiency Per Cent
50	47
100	60
150	68
200	73.5
300	78
500	81
700	82

Table II—Average Efficiency of Centrifugal Pumps

Rating of Pump		Efficiency Per Cent
Gal. Per Min.	Head in Ft.	
100	10 to 50	25 to 50
500	10	50
	20	60
	50 up	65
1000	10	55
	20	63
	50 up	68
2000	10	58
	20	65
	50 up	70
4000	10	60
	20	65
	50 up	72
8000	10	63
	20	70
	50 up	76

A centrifugal pump has high efficiencies over a portion of its possible operating range and low efficiencies over other portions. From a power consumption viewpoint it is important that a pump be selected which will normally operate within the efficient portion of its range. If the pump is to operate against a range of heads, as against a floating standpipe, the range of heads and the range of good pump efficiencies should coincide. Power losses due to inefficient pump operation may be of great magnitude as compared with motor losses. Pumps operated off-rating may be very inefficient. The over-all efficiency of pump and drive is the important result desired.

Volute pumps retain good efficiencies over a range of speeds if operated at favorable heads and volumes corresponding to the respective speeds. On high-pressure, multi-stage pumps, any departure from the most efficient speed is usually attended by considerable decrease in efficiency.

Pumps are driven by many types of motors, notably shunt and compound-wound motors of both constant- and adjustable-speed ratings, induction motors, brush-shifting commutator motors, and synchronous motors. The basis of motor selection involves the type of pump, nature of service, and electric system available.

The requirements of pump drives can nearly always be handled satisfactorily by some type of alternating-current motor. Unless direct current alone is available alternating current is ordinarily to be preferred both from the supply standpoint and for reasons of motor suitability.

The great majority of pumps operate at constant speed. For these drives the induction motor is eminently suited. Squirrel-cage motors, in sizes up to 500 hp., may be employed to drive centrifugal pumps but it is more common practice to use wound-rotor motors above 100 hp., or 200 hp., according to the nature of the supply system, so as to avoid objectionable starting current peaks. The induction motor with double squirrel-cage winding is now being adopted in some cases where it is desired to connect the motor directly across full voltage at start.

Starting conditions are more severe with reciprocating pumps, particularly when starting under load. Wound-rotor motors, as shown in Figs. 1 and 5, are commonly used for driving this type of pump in all but the smallest sizes.

Squirrel-cage induction motors and automatic-start motors are well suited for driving the smaller rotary pumps. Wound-rotor induction motors are desirable above 50 hp., primarily because of starting perform-

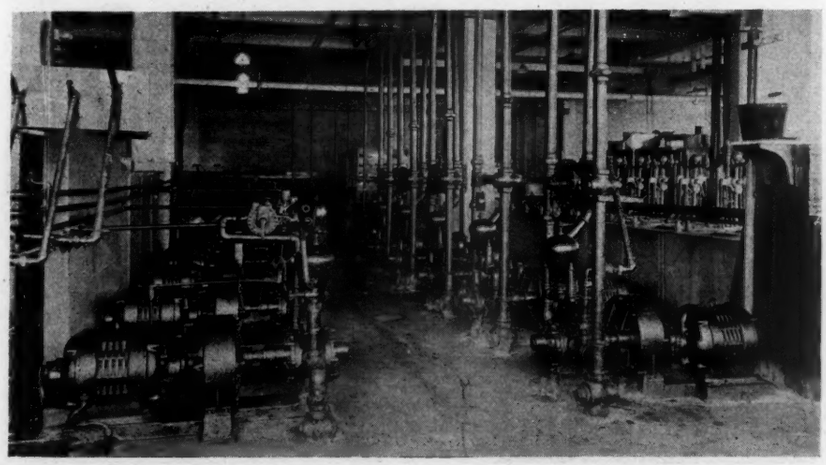


Fig. 6—Squirrel-cage motors driving through speed reducers are used on these rotary pumps.
This installation of Bowser rotary pumps is in the East Pittsburgh plant of the Westinghouse Electric & Manufacturing Company.

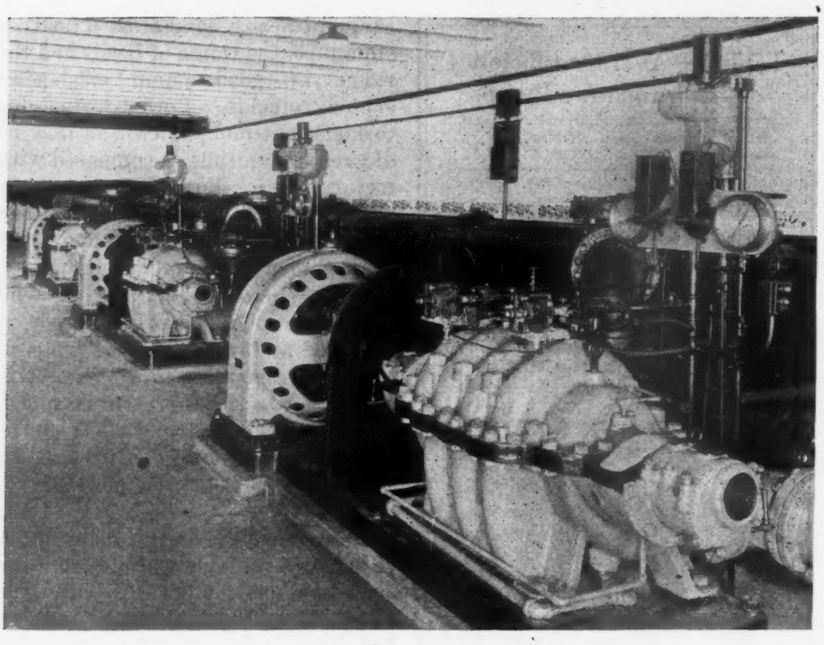


Fig. 7—Synchronous motors are used on these multi-stage centrifugal pumps.

These pumps are installed in a colliery of the Lehigh Valley Coal Co. The Allis-Chalmers centrifugal pumps are driven by Electric Machinery Co., coupled, bracket-type, synchronous motors rated at 300 hp., 1,200 r.p.m., 2,200 volts. The motors are remote controlled, a start-stop, push-button switch being located at the instrument board mounted over each motor. Cutler Hammer pressure and vacuum regulators are mounted on each instrument panel for controlling the operation of the pumps.

ance. In general the speeds of rotary pumps are rather low so that gear drive from a higher-speed motor is the most economical combination. Fig. 6 shows squirrel-cage motors connected to rotary pumps through speed reducers.

Special considerations as to the liquid pumped, such as gasoline, or benzine, may dictate the use of squirrel-cage motors and oil-immersed control equipment so as to avoid explosion and fire risk.

The synchronous motor is used to some extent for driving centrifugal pumps, notably in the larger sizes for pumps operating continuously. The high-speed synchronous motor has little advantage over the induction motor in the matter of efficiency. It has some advantage in the matter of power factor, but a high-speed induction motor driving a pump with a continuously maintained load, does not have a low power factor. In some instances synchronous motors are not available at the high speed most suitable for the pump. For large, low-speed pumps used for low and moderate heads, the synchronous motor is well adapted.

In applying a self-starting synchronous motor to a centrifugal pump drive, the pull-in torque is a main consideration. The starting torque is much less than the pull-in torque. The pump should be started with the discharge valve closed. The pull-in torque then required for churning will be about 50 to 60 per cent of full-load torque. Synchronous motors will develop this amount of torque without excessive current input. Starting conditions should be checked, however, whenever synchronous motors are applied to centrifugal pumps.

The synchronous motor offers one advantage in some instances, in that its torque decreases with decrease in voltage (with maintained excitation) less rapidly than that of the induction motor.

The 60-cycle system has a measure of advantage as related to centrifugal pump drives, as it offers a synchronous speed of 1,800 r.p.m. which is often more advantageous than the maximum of 1,500 r.p.m. available with 25 cycles. It also offers a greater variety of speeds.

Where direct current only is available the compound-wound motor is usually to be preferred for constant-speed pump drives. This type of motor is desirable for use with reciprocating pumps partly because of its better ability to meet the severe starting requirement. Shunt-wound motors are not well adapted to centrifugal pump drives as they are too sensitive to voltage fluctuation. The centrifugal pump, with its column of water, represents a load of high inertia. A compound-wound motor for centrifugal pump service should have only a moderate series field, approximately 10 per cent series ampere-turns. Such motors are available, having been specifically designed for this service.

In a concluding article, to be published in a succeeding issue, the application of the various types of motors to the different forms of pumps will be considered more in detail.

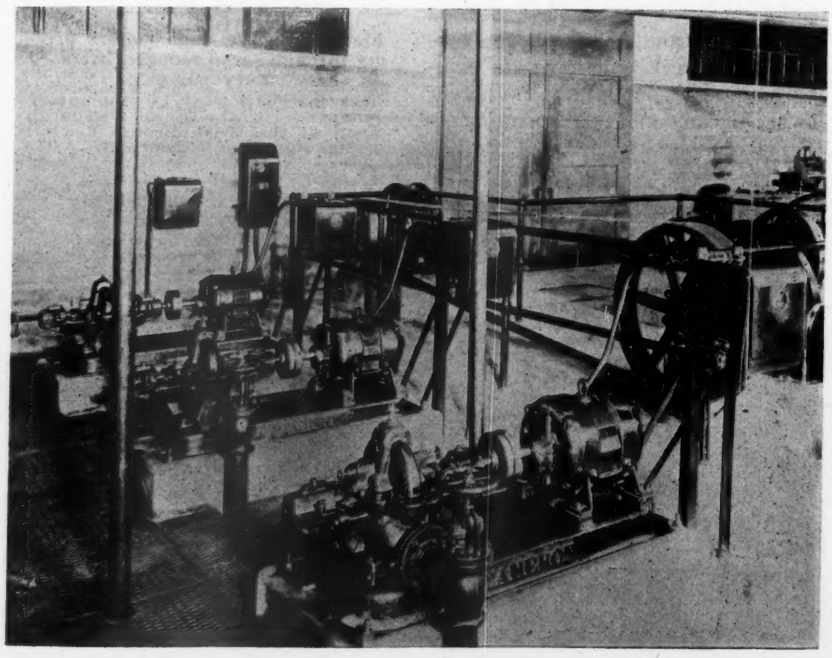


Fig. 8.—The characteristics of the squirrel-cage motor make it the ideal drive for centrifugal pumps of the smaller capacities.

Westinghouse squirrel-cage motors and compensators are used on these Cameron centrifugal pumps.

PREVIOUS ARTICLES in this series on lubrication, which have appeared in Industrial Engineer are "Using Oils and Greases for Industrial Lubrication" in the December, 1925, issue, and "Specifications for Oil and Grease Lubricants" in the March, 1926, issue. This present article will cover briefly a discussion of some of the methods and equipment used in the application of lubricants to lineshafts and machines. The lubrication of engines and turbines will not be included as this is an extensive subject in itself; the lubrication of motors will be covered in a later article.

Some types of

Equipment Used for Applying Lubricants

either continuously or intermittently to the different designs of bearings used on machines and lineshafts

Here a Zerk-Alemite compressor or grease gun with the low-pressure nozzle is being used to fill Hyatt hanger bearings.

By FRANK E. GOODING

Associate Editor, Industrial Engineer

METHODS of applying lubricants depend largely upon the provision for lubrication which was made by the manufacturer of the equipment and on the type of lubricant used. Even though much of the responsibility for the necessity of machine and drive maintenance is due to the use of the wrong type of lubricant or to its improper application, this problem is only beginning to receive its proper recognition and consideration in industrial plants.

The development of improved methods of lubricating industrial and power-transmission machinery has been along the lines of improved bearings, investigations to determine the proper lubricant for each class of work, and improved methods of applying it. In the old-time rough bearing, which did not fit closely on its shaft, the main problem was to apply sufficient lubricant frequently enough to maintain an oil film between the shaft and each bearing. Oil was applied periodically by means of a hand oiler; a bearing which was forgotten would often cause trouble later. Due to the fact that oil could run out of the open bearings so easily, the use of grease instead of oil became more common. The first improvements made in bearings were along the lines of making better bearing metal, investigations into the proper types of oil grooves, and bearings which fitted more closely on the shaft. More recently, when studying lubrication problems, attention has been directed towards the use of the proper lubricant for each type of service and operating condition and toward the improvement in methods of applying the lubricant.

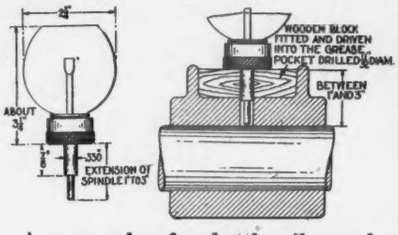
It was realized in these early studies that any interruption to the main power transmission service would interrupt an entire group of machines and so effort was directed toward the development of reliable power transmission bearings. As a result the ring, chain, wick and collar types of bearing oiling systems were developed. The bearing in each of these cases consists of a reservoir with one of the above devices for carrying and distributing the oil over the surface of the shaft. All of these bearings are well known and have been described in a previous article in the May, 1924, issue of INDUSTRIAL ENGINEER entitled, "Babbitt, Ball and Roller Hanger Bearings," and so will not be taken up at length here. The development of the automobile has been responsible for much of the investigation and study of lubrication problems. The results are being applied to the solution of industrial problems.

It is rather difficult to classify the equipment and methods of applying lubricants. This is largely due to the fact that greases and oils are both used as lubricants and also because of the wide variety and varying types of operating services which are found in industrial plants. Devices for applying lubricants, however, fall roughly into three gen-

eral classes: (1) Oil or grease containers located on the bearings; from these containers the lubricant drips or flows onto the shaft. (2) An oil reservoir around or near the bearing surface, together with some method of carrying the lubricant to the bearing surface; ball and roller bearings and bearings with the wick, ring, chain, collar, or splash type of lubrication belong in this class. (3) Pressure feed lubrication. This third class of lubricating equipment may be further subdivided into: (*a*) Continuous, such as where the pressure is applied by a pump or by a ratchet operated by a stroke or movement of the machine, or by the pressure of gravity from a storage tank placed overhead. (*b*) Intermittent, such as the stationary or portable grease guns which are operated at intervals by hand. (*c*) Circulating systems which differ from classification (*a*) in that the oil is circulated through the bearings, cleaned (in some cases), and recirculated.

The use of a closed container, such as an oil or a grease cup, is one of the most commonly used methods of applying lubricants. These cups are attached to the bearings and feed the lubricants through an opening or oil hole. These cups are of such a variety of types and are so well known that it is not necessary to go into extensive detail in explanation or illustration of them. Many types of oil cups can be regulated to feed a drop of oil regularly and are provided with sights so that their operation may be observed. Grease cups are frequently provided with springs behind a diaphragm which apply pressure to the grease.

Two of the important advantages of the closed oil or grease cups are that they require only periodic attention and that they also cover the oil hole so that dust cannot enter.



An example of a bottle oiler and one method of application.

The description of this oiler is given in the text. The projecting sleeve fits into the oil hole and the spindle touches the shaft. The illustration at the right shows the application of a bottle oiler to the grease pocket of an old bearing.

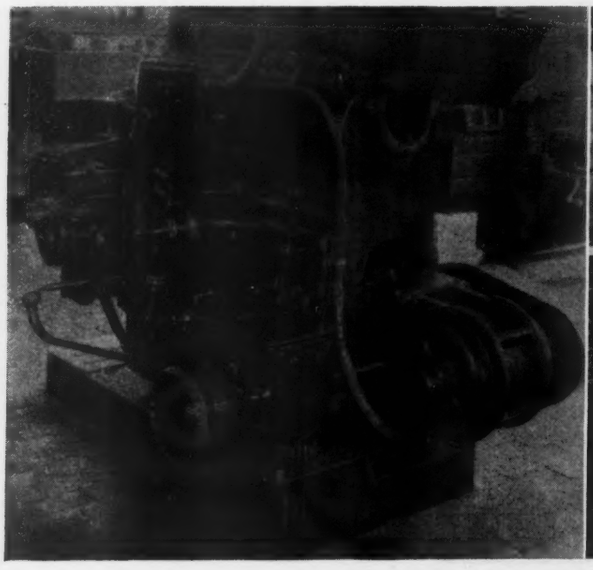
In very dusty locations, however, care must be exercised in the filling of these containers, particularly grease cups, so that dust and dirt do not get into the grease and find their way into the bearings. On some machines, particularly in those industries in which dust is not created to any extent in the process or operation, oil holes are found in considerable number. However, the tendency in lubrication practice is largely toward protecting these openings at least with some type of small cap which automatically keeps the opening closed. Manufacturers of a large proportion of the better class of machinery provide a more positive type of lubrication wherever possible. However, on many types of machines, particularly those used where the work requires only intermittent operation, oil cups have many advantages. All oilers of this type are filled by hand.

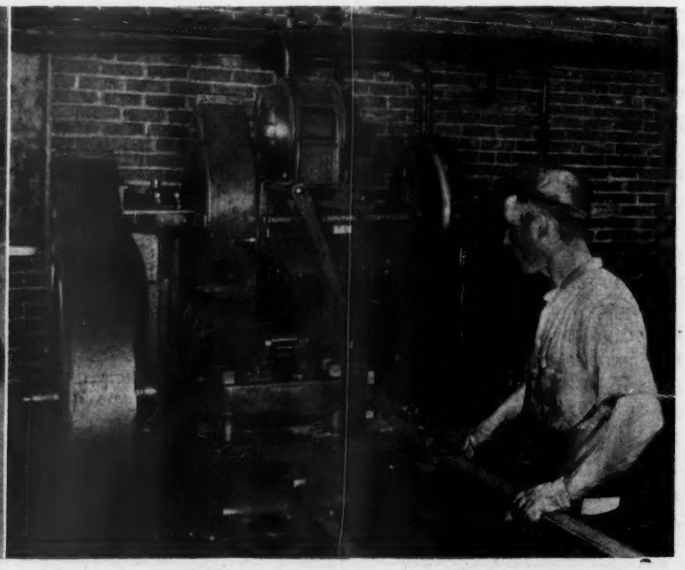
The rate of feed on sight-feed oilers is usually measured by the number of drops per minute. The general practice with these oilers is to feed the oil too rapidly; this gives the bearing too much oil which frequently causes as much trouble as too little oil. In practically all cases any excess of oil runs out, catches dust, and dirties up the machine. In addition, there is the cost of the unnecessary excess oil used. Pressure feeding grease cups usually have some method of regulating the flow of the grease and also of shutting it off when the bearing is idle, either by relieving the pressure, or by closing up the connection between the grease reservoir and the bearings, as shown in the accompanying illustration of a Chicago automatic spring compression grease cup. Cups of this general type will feed any non-liquid lubricant. The amount of lubricant in the cup is indicated by the height of the feed screw; the flow is regulated by the stopcock in the stem.

The bottle oiler, which is shown in the illustration on this page, is a

Two different types of positive-feed lubricating systems which are used in industrial plants.

The illustration at the left shows a Madison-Kipp lubricator (Madison-Kipp Corp., Madison, Wis.) which lubricates not only the bearings, but also the slide of a shaper. The oil feed adjustment is set so that one filling will last about a month. The amount of oil remaining in the lubricator, which is located at the lower corner of the machine, is indicated by an oil gage. The lubricator rocker arm is actuated from the crossfeed mechanism. The eye spring forming machine at the right is lubricated by a McCord lubricator (McCord Radiator & Manufacturing Co., Detroit, Mich.) which is located on the front of the machine and distributes the oil to the various bearing surfaces through a system of pipes which may be seen in the illustration.





simple oil container and provides an easy method of automatically applying the lubricant to a bearing. This oiler consists of three essential parts: A glass container or bottle of about 4-oz. capacity, a tight-fitting cap, and a spindle. The bottle has a short neck and a threaded ferrule on which the cap can be screwed. The cap is threaded to fit the ferrule on the bottle, and contains a washer which makes a tight joint on the neck of the bottle. This cap has a projecting sleeve which is drilled to permit free movement of the spindle. The spindle consists of a straight piece of round steel about 0.187 in. in diameter. One end is flattened and placed inside the bottle to prevent the spindle from dropping out. In use the bottle oiler is placed in an inverted position (with the cap down) and supported in the bearing so that the end of the spindle rests on the journal or shaft. Since the bottle oiler is inverted and air tight, except for the spindle clearance, oil cannot leak out unless air enters. When the shaft is stationary, no air enters the bottom and no oil is lost. When the shaft is in operation the spindle of the bottle oiler is given a motion so slight that it can scarcely be detected. This motion is sufficient, however, to result in a pumping action which causes air to enter and oil to leave the bottle at a very slow but uniform rate through the small clearance space between the spindle and sleeve. As the oil flows down the spindle to the shaft, it is distributed to the bearing surfaces and so builds up the oil films.

Small bearings up to about 6 in. in length, can generally be lubricated satisfactorily by a single oiler unless the shaft is over 3 in. in diameter.

Two bottle oilers will generally take care of any lubricating demand, on bearings up to 10 in. in length and on shafts under 6 in. diameter. On large shafts or long bearings three or more bottle oilers are frequently used. These general considerations, are of course, influenced by the load on the bearing and the speed of the shaft. Heavily loaded bearings, of course, require more lubrication than bearings which merely support the weight of the shaft. Also, slow-speed bearings reduce the activity of the spindle of the bottle oiler and therefore require a greater number of oilers than have been indicated in the general statement just given. Slow speed also causes poor oil distribution and so the oil should be applied in more places along the length of the shaft.

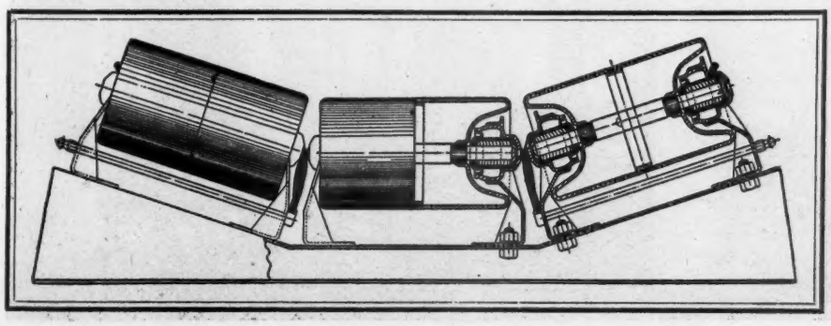
The Zerk-Alemite grease guns or compressors are filled through the pistol grip handle.

This type of gun is used for lubricating bearings or lubricant containers under pressure. This compressor has a different type of nozzle from that used in filling cavity bearings, such as on a roller-bearing lineshaft, as shown in the illustration at the head of this article. One turn of the crank on the filler tank loads the compressor. This tank weighs only 34 lb. and is carried around by the oiler to the different departments. Pressure is applied by placing the tip of the compressor against the fitting on the bearing and pushing down on the handle which forces a definite amount of grease into the bearing.

Bottle oilers may be used on the lubrication of almost any kind of horizontal bearings on shafting and machinery. The bottles, with spindles and caps attached, are filled in the oil room and interchanged at the machine. If this is done carefully, there is little opportunity for dust or dirt to enter the bearings. Bottle oilers are often used on bearings difficult of access while the machine is in operation. The oilers may be filled and inserted while the machine is idle and as they usually contain enough lubricant to last a week or more, even under continuous operation, the lubrication problem is cared for until the machine is shut down at the end of the week. This removes the necessity of shutting down for oiling, and also relieves the operator of the annoyance and danger of oiling inconveniently-located bearings while the machine is in operation.

When necessary these oilers may be mounted in an inclined position, providing the angle from the vertical does not exceed 30 deg. In such cases, the spindle rests squarely on the journal. A single example of the advantages of using a bottle oiler to regulate the flow of the oil, instead of relying on the haphazard method of oiling a bearing whenever the operator thinks about it, is taken from the experience with a blower located in a very dusty place. Under the former method of lubricating by hand, approximately a gallon of oil was used per day. Even then considerable trouble was experienced with hot bearings. The installation of bottle oilers and changing to an oil better adapted to such bearings resulted in a reduction in the bearing temperature and also reduced the quantity of oil used to about one pint in two weeks. One of the big advantages of an oiler of this type is that the feed is in proportion to the speed and cannot be increased because the operator thinks that the oil is feeding too slowly.

The second class of bearings considered consists of an oil reservoir around or under the bearings and some means whereby the oil is carried up to the bearing surface. Ball and roller bearings which are surrounded by oil or grease, are bearings of this type. The numerous



Here a three-pulley conveyor idler equipped with Hyatt bearings is greased by the pressure system of lubrication. Flexible hose connects with the tubes, carrying the lubricant to the four bearings at the center of the stand.

types of bearings which use rings, chains, collars or wicks to carry the oil to the bearing surface are also included in this classification. Among the big advantages of these bearings is that they require only infrequent attention and filling, usually at less frequent periods than the types of bearings included in the first classification. Among the disadvantages, however, are the inability to see that the oil-carrying device is in operation and also that it is difficult to see just how much oil is in the reservoir with the resultant possibility of under-filling, or over-filling. Bearings of this type are, however, very widely used and operate satisfactorily with a reasonable amount of care and attention.

Probably the larger proportion of lineshaft bearings come under this classification, including, of course, the ball and roller lineshaft hanger bearings.

Bearings in which the lubrication is obtained by means of an oil bath or splash system also fall under this second classification. The tendency in gear lubrication seems to be towards using the bath or splash system for lubricating gears and worms, even though they may be traveling at a comparatively low rate of speed. This gives a positive application of the lubricant to the wearing surfaces and is considerable of a contrast to the older method of applying a thick lubricant to the surfaces at irregular periods. On large and high-speed gear trains, such as are used in steel mills and on turbine reduction gears of large size, the tendency is towards the use of a circulating system in addition to the bath.

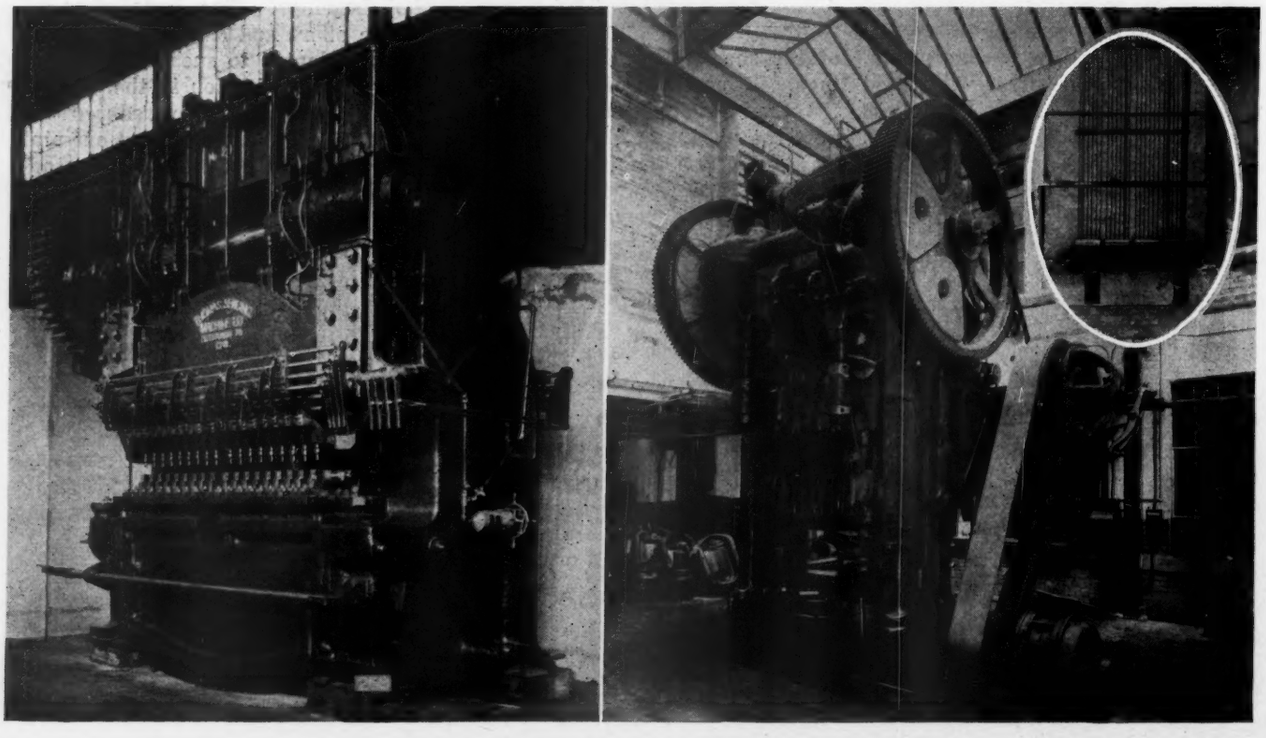
Silent chain drives are often lubricated by enclosing them in a case containing oil and having the chain dip into the oil at the lowest point. Where it is not feasible to use a case, chain drives are frequently lubricated by applying a heavy oil with a brush, to the back of the chain.

The third kind of lubricating device which was indicated, supplies the lubricant through a pressure feed device. One of the earliest types of pressure or positive-feed lubricating systems which was developed was what may be called the continuous system. This was originally adopted for engine and pump lubrication and generally was connected into the equipment so that a definite amount of lubricant was applied with each stroke or cycle of movement of the mechanism. Some of this equipment has been applied to machinery. However, but few machines need new oil each stroke or revolution and so as the equipment was originally designed, it was not well adapted to machine lubrication. Modifications, however, are widely used.

One of these types of devices which automatically feed oil to a number of bearings has been developed by the Madison-Kipp Corporation, Madison, Wis. This has been applied to machine tools and some special machinery. The lubricator consists of a pump which is operated by the machine through a worm gear. This lubricator may be regulated, it is stated by the manufacturer, to feed from 1 drop to 15 drops of oil per minute through anywhere from 4 to 100 outlets, and operates only when the machine operates. The oil is distributed to the various bearings from a central lubricator through small pipes which lead into the intricate and practically inaccessible (to a hand oiler) parts of the machine and thus assure continuous lubrication of the parts which would likely be neglected

Safety and reduced maintenance are two of the important reasons for using force-feed lubrication on large machines like these.

With force-feed lubrication the accident hazard and the possibility of human forgetfulness are largely eliminated. The punch press at the left is lubricated by a Keystone semi-automatic safety system (Keystone Lubricating Company, Philadelphia, Pa.) of grease lubrication. The safety lubricator is shown at the right end of the machine. Pressure is applied to the grease in the lubricator by turning the handwheel. This forces grease through the system of pipes to the various bearings. The operation of this lubricator is explained further in connection with the group of illustrations on page 217. The 500-ton Ferracute press at the right is lubricated from the McCord force-feed mechanical lubricator, (McCord Radiator & Manufacturing Company, Detroit, Mich.) which is mounted on the wall back of the machine, as shown in the oval. The oil is distributed to the various bearings through a system of pipes.

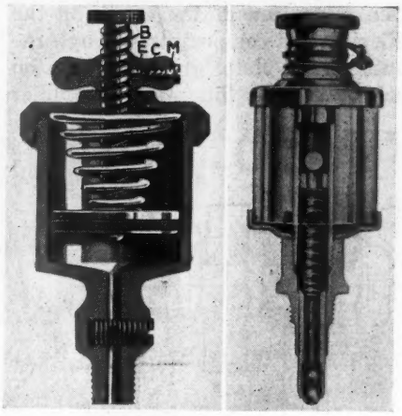


if the lubrication was wholly dependent upon the operator or an oiler.

Still another type of force-feed lubricator has been developed by the McCord Radiator and Manufacturing Co., Detroit, Mich. This also is a positive-feed device operated by the machine and the amount of oil delivered to each individual bearing or part may be adjusted, it is stated by the manufacturer. This adjustment takes care of the fact that some bearings require more oil than others. The oil is placed in a reservoir with a gage glass which indicates the amount of oil remaining. Practically all the attention required is to refill the reservoir as occasion demands. In the McCord lubricator the oil is also forced to the various parts of the machine through tubing which may connect up with practically any part of a complicated machine.

A modification of a system of lubrication, which was originally designed for engines, pumps and other reciprocating machines, is also applied by Wm. W. Nugent & Company, Chicago, Ill., to other lines of heavy machinery.

Still another type of positive-pressure lubricator is arranged to lubricate at the will of the operator. One device of this type which uses grease is manufactured by the Keystone Lubricating Company, Philadelphia, Pa. In the Keystone safety system of lubrication, grease is forced from a central grease station lubricator through pipes or tubes to the various bearings. This may be either intermittent or continuous according to the system used. With the intermittent system of lubrication the pressure is applied by the operator by screwing down the piston in the grease chamber or lubricator at intervals. This distributes the grease through the various tubes to the different bearings intermittently. A pressure reducing or regulating plug governs the quantity of lubricant applied to each bearing. This regulating plug may also be used to take care of the difference in distance between the lubricator and the various outlets which would affect the pressure on the grease at the different bearings.

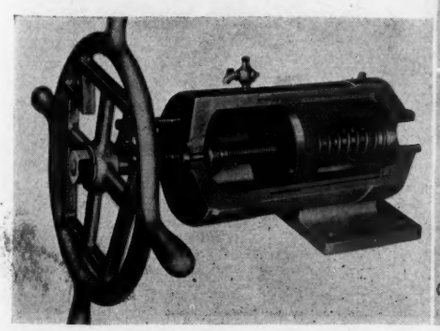


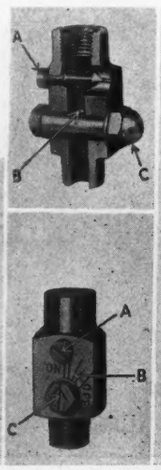
Types of grease and oil lubricators which provide continuous feed.

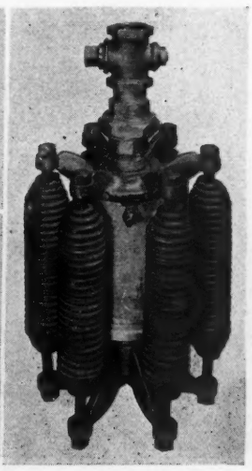
The Chicago compression grease cup at the left (Ohio Injector Co., Wadsworth, Ohio) provides an adjustable spring compression on the grease in the cup. The amount of flow is regulated by turning the screw in the outlet. The Kelly lubricator at the right (Kelly Lubricator Co., Syracuse, N. Y.) gives a steady feed of oil to the bearings through the capillary action of the balls in the tip. One of these balls rests on the bearing and the other almost closes the stem leading to the oil cup. The rotation of the shaft rotates the ball which carries the oil down to the bearing.

This is the mechanism which controls the Keystone safety grease lubricator.

The illustration at the left shows the compression chamber and the handwheel for applying the pressure to the grease. The cross-section and exterior views of the pressure-reducing valve (center illustration) indicate the method of regulating the amount of grease fed to the bearings. This valve is placed directly at the bearing and the amount of feed controlled by turning the screw *C*. The needle valve *A* is used to check the amount of pressure applied at the bearing. The automatic spring cup at the right is filled from the safety lubricator (left). The springs then apply pressure to the line to force the grease to the various bearings under continuous pressure. This is part of the Keystone equipment (Keystone Lubricating Company, Philadelphia, Pa.) for industrial grease lubrication.







The Keystone system of lubrication may be made continuous by the addition of an automatic spring cup, such as is shown in an accompanying illustration. This spring grease cup is filled by screwing down on the hand lubricator which forces out the diaphragm of the spring cup. The springs then apply the pressure to the piston which gives a continuous pressure on the lubricating system and keeps the grease in the tubes under pressure. The grease is carried to the various bearings through light but strong tubing, or through a heavy grease-proof hose.

Still another type of intermittent lubricating device is incorporated in the Bowen system, manufactured by the Bowen Products Corporation, Auburn, N. Y. In this the tubes run from a pressure pump to the various bearings in much the same way as in the other positive lubricating systems. Oil is delivered to the various bearings by pushing down either by hand or by foot on a lever which operates the plunger of a pump which applies the pressure that is necessary to force the oil to each bearing. The Bowen system was developed for automobiles but is also applied to machine tools, and various other types of machines. The amount of lubricant delivered at each stroke of the piston may be regulated so as to govern the flow to the various bearings. Oil feeds down to the pump from a gravity tank; a strainer in the tank removes any sediment or foreign matter in the oil which might clog up the oil pipes in the system.

The big advantage of all of these positive-pressure methods of lubrication is that oil or grease is delivered to all bearings at the same time and so none are neglected or overlooked. In addition, in many types of machines it is unsafe for an operator or oiler to attempt to lubricate certain parts while the machine is in operation. This is particularly true of presses and other machines with large gears where a slip may cause a serious accident. Such bearings or oiling places are frequently neglected because of the danger involved when hand oiling is relied upon. With a positive oiling system such places receive their proper amount of lubricant. Some of the accompanying illustrations show various machines equipped with different types of positive oiling systems. It is com-

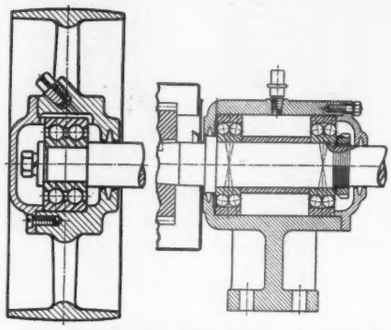
paratively easy for an operating man to visualize the difficulty incidental to the hand lubrication of some of the oil holes on these machines.

Comparatively recently as an outgrowth of the lubrication of automobiles the grease gun method of lubrication has been applied to industrial work. This equipment consists of a portable gun which applies the grease, or in some cases oil, under pressure, through a fitting in the oil hole of the bearing. As the lubricant is forced in under high pressure, it tends to work the old lubricant out to the side and carry with it foreign material or metallic particles which may be in the bearing. The fitting is kept closed by a ball on a spring in the opening. Fittings may be placed on the top, side or bottom of a bearing as may be most convenient for the oiler.

Two types of grease guns are manufactured by the Bassick Manufacturing Company, Chicago, Ill. One of these is known as the Alemite system and the other as the Zerk-Alemite system. The Alemite gun or compressor consists essentially of a cylinder, a piston which is screwed down to apply the pressure to the grease and a flexible or stiff tube or hose which is connected onto the nipple at the bearing.

Recently, however, the Zerk gun or compressor has been modified for industrial purposes and a special portable filling unit is used in connection with it, as shown in accompanying illustrations. The compressor consists of a cylinder to contain the grease, a pistol grip or handle connected to the main plunger and a nozzle with a small plunger to apply the high pressure to the grease. In operation, this gun is merely placed against the nipple on the bearing and the operator pushes down on the pistol-grip handle which acts through the plunger to force a definite quantity of grease into the bearing.

A special, portable filling unit is used in connection with the Zerk compressor for industrial work. This filling unit weighs 34 lb. when filled with 20 lb. of grease and can thus be carried around from department to department by the oiler. One revolution of the crank on the filler loads a compressor through the butt of the pistol grip as shown on page 215. In this way, the oiler always has plenty of grease with him and can fill the compressor, even in a dusty location, without exposing the grease to dust or other gritty substances that may be in the air.



Method of lubricating a ball-bearing loose pulley and a chain drive mounting.

The loose pulley at the left is fitted with SKF ball bearings. The provision for grease lubrication is indicated. The illustration at the right shows the mounting of the bearings for a chain drive connection to a textile mill. The chain drive is connected on the overhung sprocket at the left and the shaft extension at the right carries the pulley. These two sets of SKF ball bearings are spread apart and the chamber for grease lubrication is placed in between. Care must be exercised in the lubrication of ball or roller bearings to see that the grease or oil chamber is not filled too full of lubricant.

Where the Zerk-Alemite gun is used for filling cavity bearings, such as ball and roller bearings, or other grease reservoirs, where the lubricant is not necessarily applied under pressure but the gun is simply used as a filler, the special, high-pressure nozzle is removed and a straight tip placed on the gun. This is especially advantageous on ball and roller bearings where grease is not applied to the bearing under pressure. Furthermore, if the ball or roller bearing is completely filled, the bearing is likely to heat due to the churning of the lubricant. For this reason, it is usually unwise to fill a ball or roller bearing more than about one-third to one-half full of lubricant. With this low-pressure attachment, the gun is used merely as a filler and does not create pressure in the bearing.

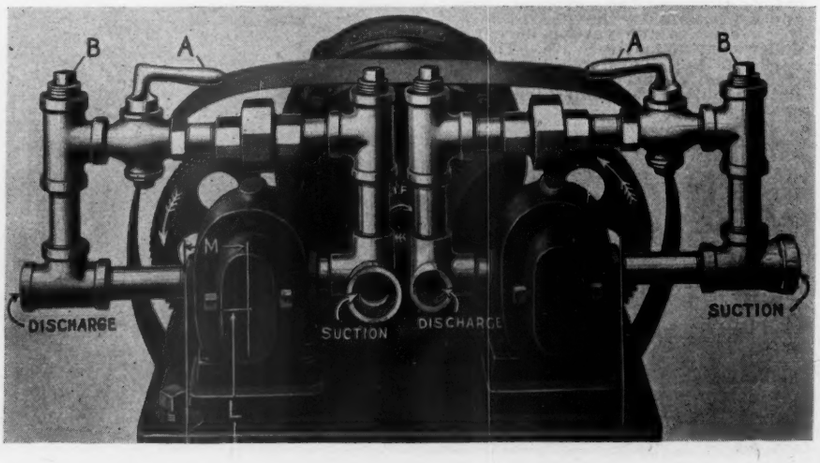
Another type of high-pressure lubricator, known as the Dot lubricator, which is manufactured by the Carr Fastener Company, Cambridge, Mass., is used with either oil or grease. Pressure is applied by a turn of the handle, which also locks the tip of the gun on the special fitting at the bearing. The gun can be released from the fitting by turning it to the left.

A portable pressure gun, manufactured by the Adams Grease Gun Corporation, New York City, applies high-pressure grease lubrication through the operation of a lever handle. Special fittings are provided whereby the Adams gun may be used on the bearing fittings of the other standard systems of portable, high-pressure lubrication.

Any of these portable, pressure gun systems of lubrication may be applied to practically any type of machine or other bearing merely by putting a special fitting into the oil hole. In this way, any old machine or lineshaft can be quickly changed over to a more modern type of lubrication.

Still another type of pressure lubrication is obtained through the so-called circulating systems. In these, the oil is forced through the bearings under pressure, cooled, usually filtered or purified, and recirculated. Such systems are frequently used around large gears, such as in steel mills, on the helical or herringbone reduction gears on

(Please turn to page 228)



This motor-driven, duplex pump is used in a circulating lubrication system.

This pump is manufactured by Wm. W. Nugent & Company, Chicago, Ill., and is used to force the oil through the bearings of the machine and also through the oil filter. Filtering and cooling are important features of any circulating oiling system.

Things that you should know about

Control Equipment for Industrial Trucks

and small, battery-propelled, industrial locomotives, with graphs and diagrams that will aid in selecting the type best suited to the operating conditions

By R. B. HUNTER
Development Engineer, The Cutler-Hammer Mfg. Co., Milwaukee, Wis.

WITH the increased use of battery-propelled industrial trucks, the question of the proper types of controllers to be employed with them becomes of importance, and an outline of the principles involved in their selection and operation may be of interest.

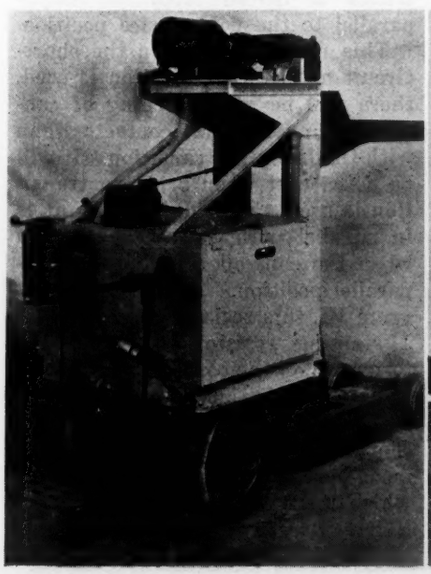
Problems arising in the use of control equipment for battery operation are somewhat different from the problems encountered with the control for motors in ordinary power service. These differences arise from three causes: (1) The vehicle motor is usually designed for relatively low voltage, because of the high cost per volt of the storage battery. (2) The size and cost of the battery limits the energy available without recharging, and for this reason it is necessary to conserve the energy of the battery to the highest possible degree. (3) The service is extremely severe; vehicle controllers are subjected to more abuse than controllers in almost any other class of service.

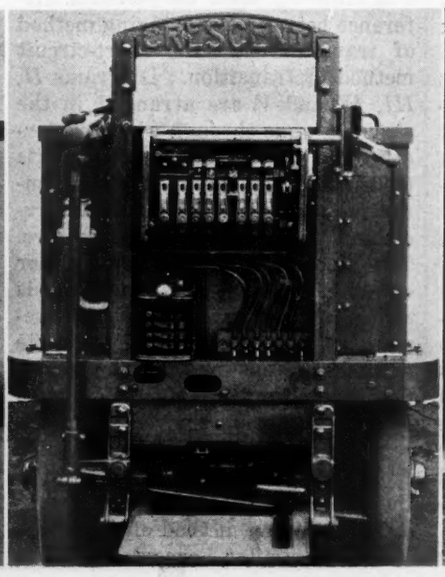
For these reasons, vehicle controllers must be ruggedly constructed and usually are of relatively large size. The electrical parts must be made unusually heavy to reduce the voltage drop and the power loss, and the mechanical parts must be sufficiently strong to withstand the severe service. The controller must also provide special features that tend to reduce energy losses. The expense of these features is warranted by the battery limitations just noted, whereas this expense would not be justified in a controller for a motor deriving its energy from a power plant of conventional type.

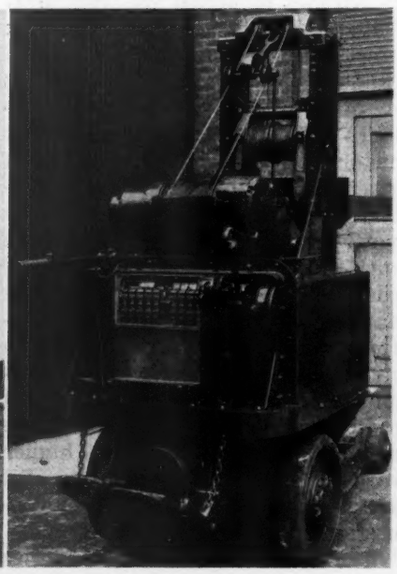
Energy losses in the electrical system of a battery-propelled vehicle are of two classes: (1) "Running losses," which comprise those losses that are due to the resistance of the motor, the leads, the controller contacts, the internal resistance of the battery and other parts of the electrical circuit. (2) "Accelerating losses," under which is classed the energy loss in the resistor which is introduced into the circuit to reduce starting torque to a desirable value.

The running losses can be reduced only by liberal design of the parts; that is, the wiring must be heavy and a motor having a high efficiency should be used. Running losses in the controller can be reduced by minimizing the number of contacts through which the current must flow when the controller is in the high-speed position. A reduction of the number of contacts in the accelerating positions of the controller, while desirable to reduce maintenance, does not conserve battery energy, for the contact losses are negligible compared to the losses in the accelerating resistor. By "contacts" is meant not only the contact fingers and segments which make the necessary connections, but also contacts between wires, busbars, terminal lugs, and the like. All these parts must be of ample size and should be designed so that the contact surfaces can be set up tightly.

Since in all systems of vehicle control a resistor is introduced into the circuit during the accelerating period, it follows that the efficiency of the system is lower during ac-







Figs. 1, 2 and 3—The controller is the brains of the electric industrial truck.

Interlocking the controller with the brake is a necessity on an industrial truck. This prevents having power on the motor while braking and also prevents starting of the truck unless the operator is in position to pilot it. Fig. 1 (at left) shows a Tier-Lift truck manufactured by the Lakewood Engineering Co., which is equipped with a Cutler-Hammer controller. Fig. 2 shows the controller used on the type GEL Crescent elevating platform truck while Fig. 3 shows the drum controller used on an Elwell-Parker type EL Hi-Lo Tructor.

celeration than during running. Many methods have been devised to improve the efficiency and reduce the acceleration losses by reducing the ohmic value of the resistor. All of these high-efficiency schemes make use of series-parallel control during the acceleration period; that is, certain parts of the circuit are connected first in series and then in parallel or *vice versa*. The parts of the circuit which may thus be commutated are: (1) the motor field sections, (2) the battery; (3) the motors themselves in cases where there are two motors; or (4) some combination of the above. For example, the series field winding of the motor may be split into two sections, these sections being connected in series during acceleration and in parallel during running. This gives greatly increased torque per ampere during the acceleration period.

One of the problems inherent to all of these series-parallel systems is the transfer of the parts of the circuit from the series relation to the parallel relation or *vice versa*, with the minimum of controller complication, at the same time securing desirable operating characteristics.

There are three possible methods of effecting this transition. These are: (1) the open-circuit method; (2) the short-circuit method; and (3) the bridging method. The characteristics of these transition methods as applied to various elements of the circuit will be outlined.

A common method of securing improved accelerating efficiency is to divide the series field of the motor into two sections, connecting these sections in series to accelerate the vehicle, and then reconnecting them in parallel to propel the vehicle at full speed. This method is used on practically all industrial trucks and tractors. The graph shown at *A* in Fig. 4 gives the characteristics of a typical industrial truck motor; it will be noted that for a given current drawn from the battery, the torque with fields-series is considerably higher than the torque with fields-parallel. A high value of pound-feet per ampere is desirable during acceleration and the controller is, therefore, arranged to connect the field sections in series on the first two or three points. On the other hand, the efficiency of the motor is better and the speed higher with the fields connected in parallel and the controller provides this connection on the final point.

The transition from fields-series

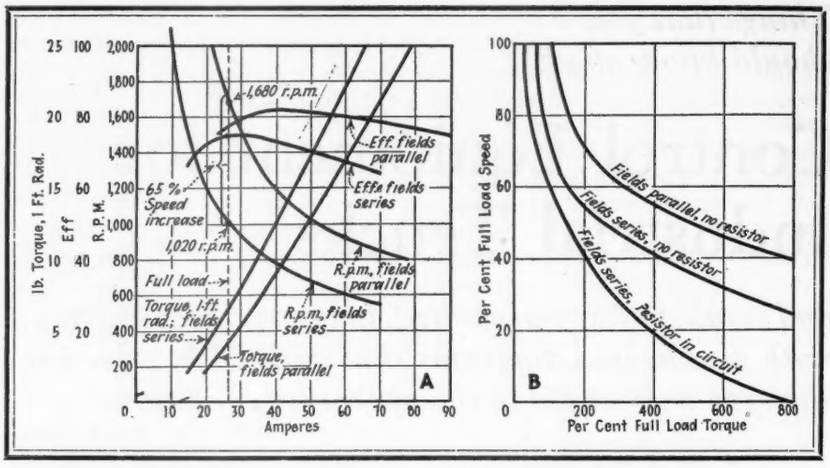


Fig. 4—Operating characteristics of industrial truck motors.

Diagram *A* shows the torque, speed, and efficiency curves for a truck motor when operating with its fields connected in series and also when its fields are connected in parallel. Note the increased torque obtained with the fields in series, and the increased speed obtained with the fields connected in parallel. Diagram *B* gives the speed-torque characteristics with fields-series and resistance, fields-series without resistance, and fields-parallel without resistance.

to fields-parallel is effected either by the short-circuit method or by the bridging method. A controller embodying short-circuit transition is shown in diagram *I* of Fig. 5. Diagrams *II*, *III*, *IV* and *V* of Fig. 5 show schematically the action that takes place when this controller is moved from the fields-series to the fields-parallel position. A controller providing bridging transition between fields-series and fields-parallel is shown in diagram *VI* of Fig. 5 and the steps of the transition are shown in the schematic diagrams *VII*, *VIII*, *IX* and *X* of Fig. 5.

An examination of the schematic diagrams will show the essential difference between the bridging method of transition and the short-circuit method of transition. Diagrams *II*, *III*, *IV* and *V* are arranged in the sequence gone through when accelerating the motor. The motor with its fields connected in series is first connected across the battery with resistance in series with the armature. The second notch of the controller cuts out the series resistance, as is shown in diagram *II*. Further movement of the controller disconnects and shorts out one of the series fields, as shown in *III*. In diagram *IV* the short is removed from the series field that was disconnected from the armature circuit and in *V* the two series fields are paralleled.

The bridging method of transition is quite similar, except that the series field that is disconnected from the armature circuit is never open-circuited, but always has a bridging resistor shorted across it, as shown in diagrams *VIII*, *IX* and *X*.

When decelerating or shutting off the motor, the difference between the two methods of transition is quite marked. Diagrams *X* and *IX* show the first step in transition by the bridging method as the controller is moved from the fields-parallel position to the fields-series position. It will be noted that field *S1-S2* is disconnected at one end but is shunted by the bridging resistor, which provides a discharge path for the magnetic energy which was stored in this field. Referring now to diagrams *V* and *VI* of Fig. 5, it will be noted that field section *S1-S2* is similarly disconnected at one end; but since there is no bridging resistor to serve as a discharge path for the stored energy, this energy will be dissipated by an arc drawn from the controller finger which disconnects point *S2* from point *S12* as the controller is moved from the fields-parallel to the fields-series position.

This means that when the short-circuit method of transition is used, there will be more burning of controller fingers and contacts than with the bridging transition. It will be noted that when bridging transition is used, the bridging resistor is in parallel with both field sections when the controller is in the fields-parallel position. As shown in diagram *VI*, this resistor serves also as a starting resistor to reduce the torque when the controller is thrown to the first position. In practice, this resistor is made of so high a value that when the controller is in the fields-parallel position, the current which flows in the resistor is negligible as regards drain on the battery, and has practically no effect on

the speed of the driving motor.

Diagram *B* of Fig. 4 shows the speeds that can be expected with various loads when a controller connected as shown in either diagrams *I* or *VI* of Fig. 5 is used. The series resistor is so proportioned that when the controller is thrown to the first notch the motor will exert a torque equal to approximately eight times the full-load torque of the motor. This is comparable to the low gear of an automobile where the normal engine torque is greatly increased by the use of a gear reduction. The torque on the first controller point is sufficient to start a very heavy load, and at the same time the speed obtained on this point when the vehicle is fully loaded is only about half of the normal speed of the vehicle. When the controller is thrown to the second notch a still higher torque will be exerted if required, and the speed with full load on the vehicle will be about 75 per cent of normal speed. When the controller is thrown to the third point the maximum speed is obtained.

Probably the oldest method of improving the accelerating efficiency of a battery-propelled vehicle is to divide the battery into two or more parts, connecting these battery sections in parallel to afford low voltage when starting from rest, and then reconnecting them in series as the motor gains speed. This method is used only on battery-propelled vehicles using a battery potential of 80 volts or higher and consequently is practically never used on the usual size of industrial truck or tractor. It is, however, used on some types of industrial locomotives and on commercial trucks. While the battery has sometimes been divided into three or more sections, it is the more usual practice to divide it into halves, thus affording two accelerating voltages. The transition from battery-sections parallel to battery-sections series can be effected either by the open-circuit method or by the bridging method. A controller providing open-circuit transition is shown in diagram *I* of Fig. 9 and a controller providing bridging transition is shown in diagram *II* of Fig. 9. As indicated by the term, when open-circuit transition is used, the circuit is completely opened in passing from batteries-parallel to batteries-series. When bridging transition is used the battery is connected first in parallel and is finally connected in series, with three intermediate points between the parallel connection and the series connection.

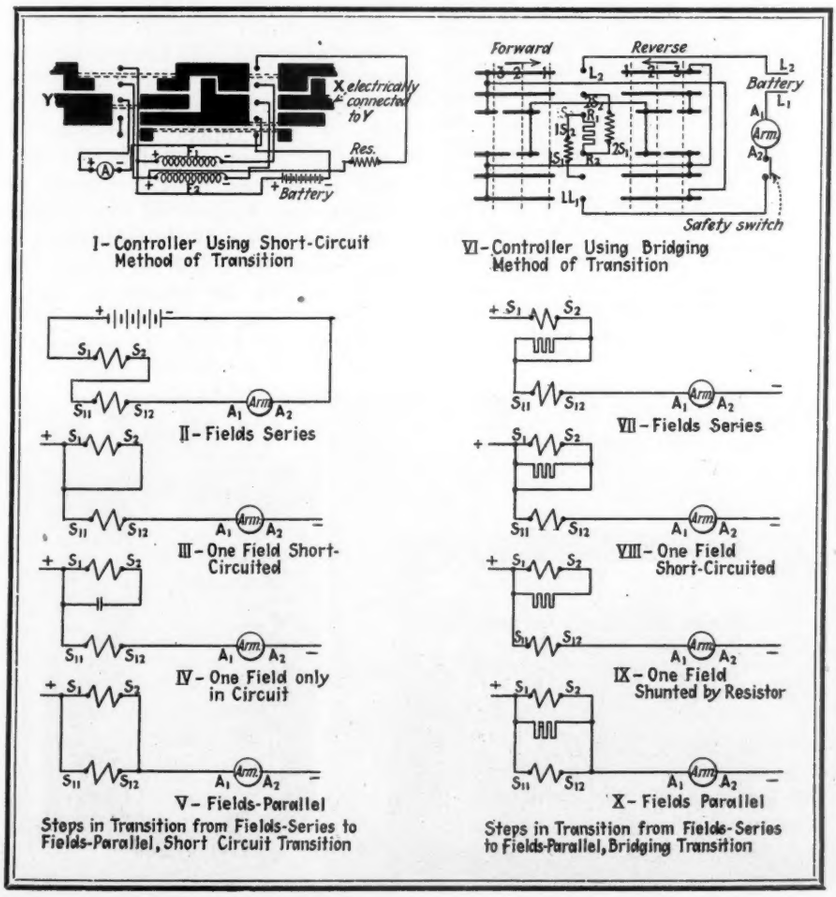
When open-circuit transition is used the torque is momentarily interrupted in passing from batteries-parallel to batteries-series, whereas when the bridging method is used the torque is continuous throughout the entire movement of the controller handle. This maintenance of torque is, however, secured at the expense of controller complications and additional resistors in which there is necessarily some energy loss. The interruption of torque during the open-circuit transition is of very short duration and this method of control is usually preferred to bridging transition for shifting from batteries-parallel to batteries-series or *vice versa*.

When the vehicle is driven by two motors, such as is often the case in industrial locomotives, the motors are connected in series during the acceleration period and in parallel during the starting period. When the motors are connected in series the voltage across each motor is only one-half of the battery voltage, and the resistor required to reduce the starting torque to a desirable value is considerably less than would be required if the motors were connected in parallel during the acceleration period; in fact, the resistor losses are reduced by one-half by using the series-parallel scheme.

The transition between motors-series and motors-parallel can be effected by any one of the transition schemes above enumerated. In practice, however, open-circuit transition is rarely used.

Diagrams showing typical controllers embodying the short-circuit method of transition and the bridging method of transition are shown respectively in diagrams *I* and *VII* of Fig. 10. Diagrams *II*, *III*, *IV* and *V* show schematically the steps in transition between motors-series and motors-parallel when the short-circuit method of transition is used. Diagram *II* shows the motors connected in series. It will be noted that there are several steps of resistance, these steps being successively short-circuited so that on the third or fourth controller point the motors connected in series have full line voltage impressed upon them. In diagram *III*, which is the first step of transition to motors-parallel.

Fig. 5—These diagrams show the difference between the short-circuit method and the bridging method of transition from fields-series to fields-parallel.


X electrically connected to Y
Y
Res.
Battery
I - Controller Using Short-Circuit Method of Transition
Forward
Reverse
Battery
Safety switch
VI - Controller Using Bridging Method of Transition
II - Fields Series
III - One Field Short-Circuited
IV - One Field only in Circuit
V - Fields-Parallel
Steps in Transition from Fields-Series to Fields-Parallel, Short Circuit Transition
VII - Fields Series
VIII - One Field Short-Circuited
IX - One Field Shunted by Resistor
X - Fields Parallel
Steps in Transition from Fields-Series to Fields-Parallel, Bridging Transition

it will be noted that motor No. 2 is short-circuited and that full line voltage is impressed on motor No. 1 in series with its resistor. The next step is to disconnect motor No. 2 from the line as shown at *B*, in *IV*. The final step of the transition to motors-parallel, as shown in *V*, is to connect motor No. 2 to the line, thus putting each motor across full voltage in series with its separate resistor. (Sometimes the connections are such that when the motors are in parallel a common resistor is used for the two motors.)

By comparing diagrams, *II*, *III*, *IV* and *V* of Fig. 10 with the corresponding diagrams in Fig. 5, it will be noted that short-circuited transition for two-motor control is analogous to the short-circuit method of transition between fields-series and fields-parallel. That is, the steps in the transition are identical, substituting motors for field sections.

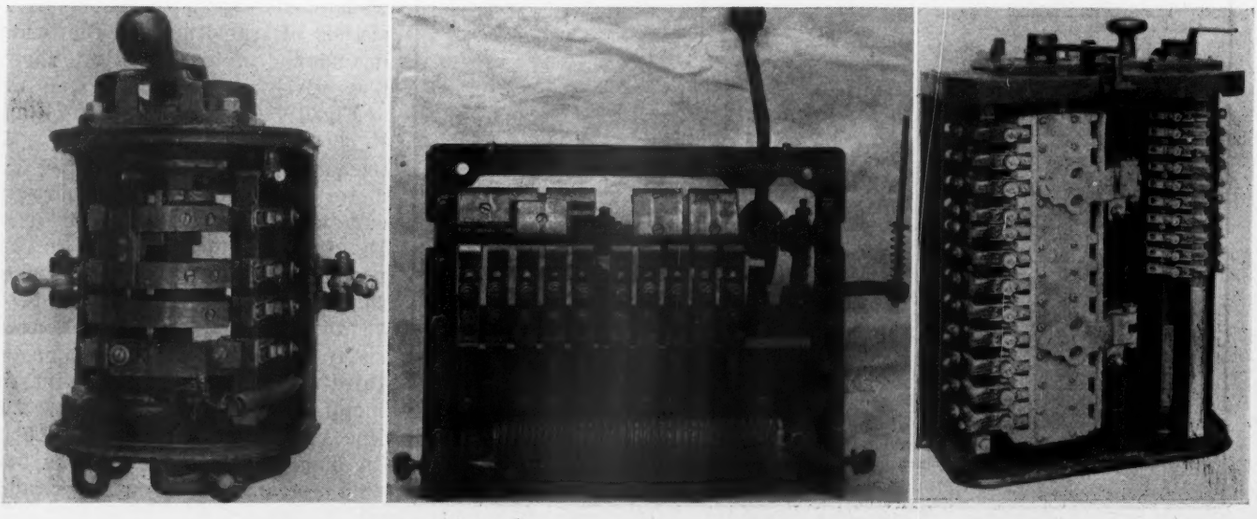
However, injurious arcing is not experienced in passing from the connections shown in *V* to *IV* of Fig. 10, whereas, as noted before, in connection with series-parallel transition of field circuits, arcing is encountered under this condition. The reason for the reduction in the arcing when commutating motors as against commutating fields in this manner, is that the motor counter-voltage tends to reduce the arcing, whereas when the fields are commutated there is no such counter-voltage, and the heavy inductance of the field tends to prolong the arc and thus burn the controller contacts.

Diagrams *VIII*, *IX*, *X* and *XI* of Fig. 10 show the steps of transition between motors-series and motors-parallel when the bridging method of transition is used. As shown in diagram *VIII*, the motors are first connected in series with resistance in the circuit, which resistor is short-circuited in three or four steps as shown by the dotted lines. The connections shown in diagram *IX* are next established. It will be noted that jumper *A* is introduced to connect the motors in series, and that the resistor circuit is opened at *B*. Connection is then made between each side of the line and each resistor, as *C* in diagram *X*. If the resistors are of proper value and the motors are equally loaded (as is usually the case), no current will now flow in jumper *A*. Diagram *XI* shows the motors connected in parallel, with jumper *A* opened.

It will be noted that in this method of transition, torque is maintained on both motors throughout the transition period. The curves in *VI* of Fig. 10 show the relation between speed and torque when the connection schemes shown in *I* or *VII* of Fig. 10 are used.

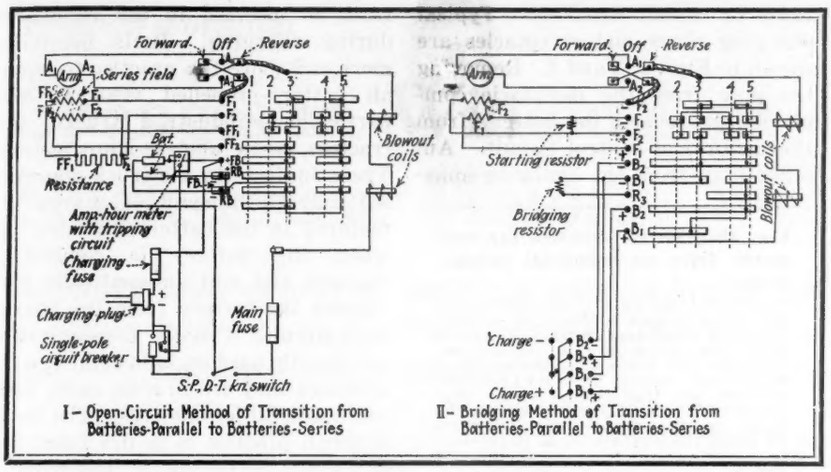
Controllers for industrial trucks are practically always of the drum type. A typical controller is shown in Fig. 6. This type of controller consists of a metal spider upon which are mounted copper segments of the proper length and spacing to make contact in proper sequence with fingers to which the external connections to the motors, battery and resistor are made. The drum type of controller is used because it is rugged and durable, is easily operated and lends itself readily to the commutation of the circuits as described above. Although the currents which must be handled by these controllers are large, due to the low voltage of the battery, the horsepower rating is low, not being greater than 10 hp. as a maximum. For this reason a manually-operated, drum-type controller is entirely satisfactory and magnetically-operated controllers are rarely, if ever, used. Magnetically-operated vehicle controllers are somewhat unsatisfactory because of the rough roads which are sometimes encountered and because of the wide variations in battery voltage which make it difficult to secure satisfactory operation of the contactor coil.

The drum-type controllers used on vehicles may be divided into two general types, namely: (1) The single-cylinder type, as used on industrial trucks; (2) the two-cylinder type, as used on industrial locomotives. In the single-cylinder type, all of the copper segments are mounted on one cylinder, and all of the operations of the vehicle are under the control of one handle. Single-cylinder drum controllers for an industrial truck for indoor factory service are shown in Figs. 6 and 7. These controllers are shown in Figs. 1, 2 and 3, mounted on



Figs. 6, 7 and 8—Here are the working mechanisms of three controllers for battery-propelled vehicles.

Fig 6 (left) shows a Cutler-Hammer drum controller for industrial truck service. Fig. 7 (center) shows controller used on the Mercury tractor. The five fingers on the right are the reversing fingers and the segments are moved longitudinally along the shaft to engage the four right-hand fingers for one direction and the 2nd, 3rd, 4th and 5th fingers from the right for the other direction. The rod at the extreme right engages with the seat on the tractor. When the operator sits on the seat, the controller is held in the running position as long as the handle is held in a speed position. When the operator gets off the seat, a pawl is disengaged freeing the drum from the handle, whereupon a spring pulls the main drum to the off position. Fig. 8 (right) is a two-cylinder controller such as used on industrial locomotives. The right-hand drum controls the direction of travel, while the left-hand drum controls the acceleration and speed.



I– Open-Circuit Method of Transition from Batteries-Parallel to Batteries-Series

II– Bridging Method of Transition from Batteries-Parallel to Batteries-Series

Fig. 9—Connection diagrams for open-circuit and bridging methods of transition from batteries-series to batteries-parallel.

trucks as they are generally used.

It will be noted that in Fig. 1, a rod connects the foot pedal of the truck with the controller. The operator rides on the platform of the truck, holding the foot pedal depressed to release the brake. The rod between the foot pedal and the controller operates a safety switch which is so arranged that as the pedal is released to apply the brake, the safety switch is opened. This safety switch is the arm connecting the bottom contacts on each side of the controller shown in Fig. 6. It serves two purposes: (1) It insures that power is not applied to the truck motor when the brake is applied. (2) By means of an interlock between the main cylinder and the safety switch, it insures that the controller must be in the "off" position before the *safety switch* can be closed, so that in case the operator leaves the truck with the controller set in a running position, it will not start if he carelessly steps on the brake pedal without first returning the controller to the neutral position.

The safety switch is purposely so made that it is closed when the controller is returned to the neutral position, and is then held closed by a latch operated by the brake pedal. When the brake pedal is released with the controller in a running position, a spring snaps the safety switch to the open position. This quick-break feature reduces the burning on the safety switch contacts, which otherwise would deteriorate rapidly because in normal operation the truck is usually stopped by releasing the safety switch and applying the brake, rather than by moving the controller to the "off" position.

The fingers shown in Fig. 6 have proven very satisfactory in controllers for battery-propelled vehicles. The proportions of this design are such that heavy contact pressure is secured and at the same time the finger does not stub on the end of the segment but rides up on it, without undue pressure on the operating handle. The finger is adjustable for wear by means of a micrometer screw and a heavy copper pigtail reduces the loss between connection and finger tips.

In the two-cylinder type, the acceleration of the motor is usually under the control of a large cylinder known as the main cylinder, and reversal is effected by a cylinder of smaller capacity operated by a separate handle. The reverse cylinder is interlocked with the main cylinder so that the reverse cylinder can be operated only when the main cylinder is in the open circuit position. All of the arcing is thus confined to the main cylinder, whose contacts are made relatively heavy and are sometimes provided with blowouts to reduce the flashing. A controller of two-cylinder type is shown in Fig. 8.

This type of controller is largely used on mine and industrial locomotives. Two-cylinder controllers are also used on road trucks, the reverse cylinder being operated by a foot pedal. In this case the reverse cylinder is held normally in the forward position by a spring, and is depressed by the operator's foot only when he wants to go backwards.

There are three factors to consider in choosing a resistor for a battery-propelled vehicle: namely, (1) the mechanical structure; (2) the ohmic value; and (3) the current-time capacity.

The mechanical structure generally used is the cast-iron grid mounted on rods and supported on pressed-steel end plates. A special grid of short rib length and small cross-section is sometimes used for industrial trucks. The low voltage and relatively low motor rating used on these trucks require a grid of comparatively low resistance and small capacity, whereas the design must be such as to offer resistance to vibration and shock. For large trucks and industrial and mine locomotives the standard grid used for general controller work is entirely satisfactory. Punched steel and alloy grids of greater strength than cast iron are sometimes used, but when mounted with reasonable care the cast-iron grid gives no trouble. Resistors made from alloy wire are also used, as is shown in Fig. 7.

The ohmic value of the resistor will vary with the type of vehicle and the service to be encountered. The results to be obtained are: (1) Sufficient torque must be provided to start the load on the first controller point. (2) The truck must start smoothly. (3) The driving wheels of the truck must not slip with the controller on the first point. When tired wheels are used, as on industrial locomotives, some difficulty may be experienced in meeting conditions (1) and (3), especially since the trailing load on the locomotive may vary from nothing to a considerable overload. If, with the controller on the first point, the torque is enough to start a heavy load, the wheels will be likely to slip if the locomotive is pulling a small load. For this reason, an extra number of points is provided on mine locomotive controllers, the torque on the first point being sufficient to start only a light load. If the load is heavy, the control handle must be moved to the second or third point to start.

Industrial trucks and road vehicles do not present this problem for the following reasons: (1) Because the variation in load between loaded and empty vehicle is not so great. (2) Because with rubber tires there is little tendency to slip the wheels. While practice varies considerably, the conservative value of current to be allowed on the first controller point for an industrial locomotive is 100 per cent of the 1-hr. current rating of the motor (or of both motors, if two motors are used) and for an industrial truck it is 150 per cent of the 1-hr., current rating.

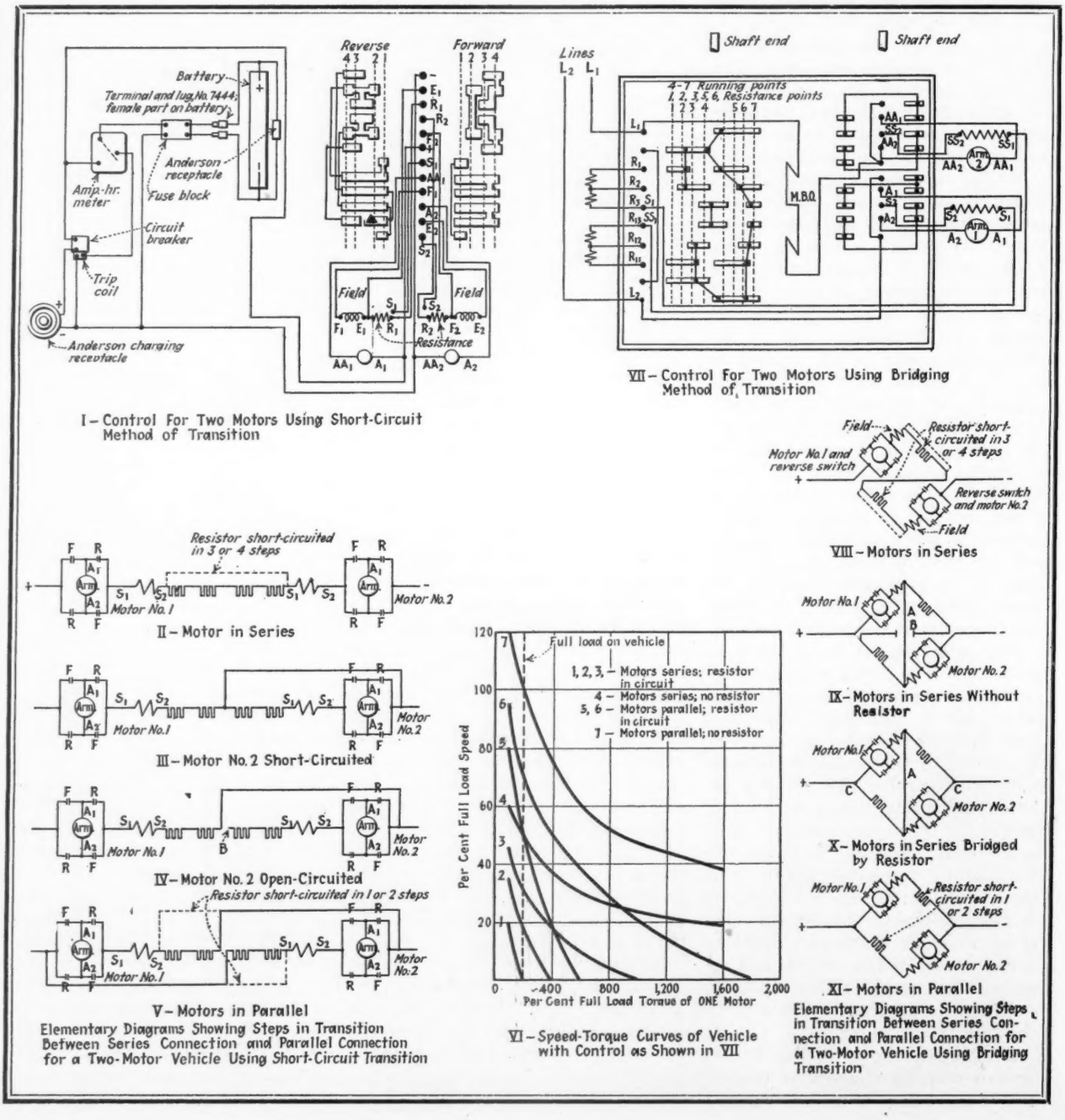
The current-time capacity of the resistor likewise depends on the

service required of the vehicle. For example, a switching locomotive will require greater resistor capacity than is required on a locomotive used on long hauls. For general service, however, resistors that meet the requirements of Electric Power Club classification No. 54 will be found satisfactory, based on the 1-hr. rating of the vehicle motor, if series acceleration is used. If series-parallel battery or motor acceleration is used, the total amount of resistor material will be only one-half of that required for series acceleration.

The remaining control accessories are the charging plug and receptacle, the ampere-hour meter, and the fuses or circuit breakers. Typical charging plugs and receptacles are shown in Figs. 1, 2 and 3. Removing the plug from the receptacle completely disconnects the battery from the motor and control circuit. Another plug from the charging apparatus is inserted in the receptacle during charging. It is becoming more and more the practice to equip all battery-propelled vehicles, and particularly industrial trucks and tractors, with ampere-hour meters. These indicate to the truck operator not only the amount of charge remaining in the battery but also tell when the battery is completely charged and will automatically disconnect the battery from the charging circuit. Circuit breakers are not usually used on industrial trucks, although they are in some cases used on industrial locomotives. The more common practice is to use fuses for protection to the motor and wiring.

Fig. 10—Control schemes for two-motor drive on industrial locomotives.

Diagram *I* shows a controller using the open-circuit method of transition and diagrams *II, III, IV,* and *V* give the steps in the transition. Diagram *VII* gives the scheme for a controller using the bridging method of transition, while diagrams *VIII* to *XI* inclusive give the steps in the transition. Diagram *VI* gives the speed-torque characteristics when using either method of control.



I — Control For Two Motors Using Short-Circuit Method of Transition

VII — Control For Two Motors Using Bridging Method of Transition

VIII — Motors in Series

II — Motor in Series

III — Motor No. 2 Short-Circuited

IV — Motor No. 2 Open-Circuited

V — Motors in Parallel

Elementary Diagrams Showing Steps in Transition Between Series Connection and Parallel Connection for a Two-Motor Vehicle Using Short-Circuit Transition

VI — Speed-Torque Curves of Vehicle with Control as Shown in VII

IX — Motors in Series Without Resistor

X — Motors in Series Bridged by Resistor

XI — Motors in Parallel

Elementary Diagrams Showing Steps in Transition Between Series Connection and Parallel Connection for a Two-Motor Vehicle Using Bridging Transition

How to work out

Changes in Windings of Single-Phase Motors

together with details of methods used in laying out starting and running windings when the original winding data are not available

By A. C. ROE

Renewal Parts Engineering Dept. Homewood (Pa.) Works, Westinghouse Electric & Mfg. Co.

and

D. H. BRAYMER

Consulting Editor, Industrial Engineer

IT IS USUALLY easy enough to rewind a single-phase motor exactly as it was wound at the factory, when all the data on the original winding are available. It is not so easy, however, to make changes in the distribution of the running and starting windings of a single-phase motor and be sure of the results, without considerable experience in this work or a full understanding of the design principles involved. In this article practical details are given on the changes that it is possible to make in such windings. In addition, complete data are shown for the windings used on a number of single-phase motors, which will be found useful when laying out a new winding or changing an old one.

SINCE the appearance of our book, "Rewinding Small Motors," published by the McGraw-Hill Book Company, letters have been received from several readers asking for information that borders on the design of small single-phase motors, rather than on the rewinding of standard designs. While it is not always advisable to change the design of small motors without first securing full data on the original winding from the motor manufacturer, there are certain fundamentals of design that can be effectively employed to determine the limitations of possible changes. An understanding of these fundamentals will help to prevent mistakes and aid in laying out a new winding when cores have been stripped before being received, or in correcting the mistakes of others who have changed the original winding so that satisfactory operation has not been secured, calling for other changes or a complete new rewinding job. The following information will be of interest in such cases.

The conditions that will be discussed are as follows: (1) Method of laying out new running and starting windings for a small single-phase motor when it is desired to rewind an old core and the original winding data are not known. (2) Method of laying out a new starting winding for a small motor in which the main or running winding is intact, but the starting winding data have been lost or a mistake was made in a previous rewinding job, resulting in such unsatisfactory operation that rewinding is made necessary.

The first point to consider in any case when a single-phase winding is changed is the horsepower the motor frame is good for, which assumes that this information is not available from the nameplate or that the nameplate has been removed. To assist in determining the rating of the frame and securing the other data, Table I has been worked up for ready reference.

In Table II data are given for 14 typical single-phase motor windings. From this information the turns per slot and per pole and the size of wire for ratings from 1/30 hp. up to 1 hp. can be secured, together with much other data that will be found helpful in many instances.

When using this tabulated information, the first thing to do is to find the rating possible for the core under consideration. To do this, measure the bore and length of the core and then refer to the data for the typical windings given and match up your data with those given in one of the examples, so as to insure a conservative rating for the core that must be rewound.

The next step is to find the total number of turns per pole. Here again the tabulated information for the 14 typical motor windings will help to simplify calculations and save considerable time, as well as avoid possible mistakes in long calculations. The examples provided give good standard methods for distributing the turns over the pole face area, that have been found to be good practice and result in good motor operation. Therefore, instead of tabulating the flux per tooth in relation to a sin curve and the ampere turns and factor for determining the conductors per slot, we can find the total flux per pole (phase) and then the turns per pole from the tabulated information presented.

To determine the total flux per pole, it will be necessary to assume values for the air gap density in lines of force per square inch. The following values will be found satisfactory:

Up to ⅛ hp. 20,000 lines per sq. in.
For ¼ hp. 25,000 lines per sq. in.
For ½ hp. 30,000 lines per sq. in.
For 1 hp. 35,000 lines per sq. in.

Then find the area of each pole in square inches and multiply this by one of the above values of lines per square inch for the required horsepower of the frame. The area of the pole in square inches equals (the stator bore in inches times 3.1416 times the length of the core in inches) divided by the number of poles. This may be expressed in the shape of a formula as follows:

$$A=(B\times N\times L)\div P,$$

where A is the area in square inches, B the bore of the stator, N a factor,

Table I—Minimum Cylindrical Inches for Maximum Single-Phase Rating of Four-Pole, 1,800-R.p.m., 60-Cycle Motors

B×B×L	Single-Phase Hp.	Remarks
18.0	¼	B equals bore of stator, and L equals length of core in inches.
30.0	⅜	$B\times B\times L$ required for six-pole motors equals 1.5 times ($B\times B\times L$ for four poles).
37.5	½	
60.0	¾	$B\times B\times L$ required for eight-pole motors equals 1.85 times ($B\times B\times L$ for four poles).
45.0	1.0	

3.1416, *L* the length of the core and *P* the number of poles.

The total number of lines of force (flux) per pole phase equals the lines per square inch times the total square inches per pole.

The turns per pole (*T*) equals (370,000 times *E*) divided by the total flux per pole. This is for 60-cycle motors only, for which data are also given in the tabulated data. *E* in this formula is the single-phase voltage.

From the above calculations the total number of turns per pole is obtained and the next step is to arrange these turns into the proper number of turns per slot or per skein. To simplify this, it can be assumed in all cases that both the starting and the running windings will be skein wound. Then turn to the typical examples of motor windings, in Table II, where the number of times that the skein is passed through each slot is given. In these examples the figure *1* indicates that the skein is passed through the slot only once, and the figure *2* that the skein is passed through a slot twice, and so on.

For example, refer to winding No. 12. In the main winding the skein passes through slot *7* once, through slots *8*, *9*, *10*, *11* and *12*, twice, and through slot *13* once, or a total of 12 times per pole. In this case the total turns per pole equals the turns per skein times the skein factor (*SF*) per pole. That is, 32×12=384 turns per pole.

On the other hand, if we know the total turns per pole and want to find the turns per skein, simply divide the turns per pole by the skein factor, *SF*, given for the windings considered in examples Nos. 1 to 14. Take for example winding No. 4. The running winding has 368 turns per pole and the skein factor, *SF*, is 8. Then the turns per skein equal 368÷8=46 turns. To convert turns per skein into turns per slot, multiply the turns per skein by the figure in each running winding slot. Refer again to winding No. 4. Here slot *5* would have 1 times 46, or 46 turns. Slot *6* would have 2 times 46 or 92 turns, and in slot *7*, where two coils overlap, the turns per slot for each coil would, of course, be 1 times 46, or 46 turns.

The next step after determining the proper number of turns, is to find the size of wire to use for the running and the main windings. In general the wire should be as large as can be wound into the slots. In estimating the sizes required the following sizes can be used, taken from the current values given in the typical windings, in Table II, below.

Up to ⅛ hp. use 250 to 375 circ. mils per ampere.
For ¼ hp. use 400 circ. mils per amp.
For ½ hp. use 425 circ. mils per amp.
For 1 hp. use 450 circ. mils per ampere.

Table II—Winding Data for Fourteen Typical Single-Phase Motors Designed for 60-Cycle Circuits

Winding No. 1—For 1/30-hp., 110-volt, 1.25-amp., 60-cycle, 1,700-r.p.m., four-pole motor, 24 slots, 2¾-in. bore, 1¼ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Main winding	1/1	2	1		1	2	1/1	2	1		1	2	1/1
Start winding				2/2	4				4	2/2			

Main winding—50 turns of one No. 25 (.0179 in.) d.s.c wire. Skein factor *SF* equals 8.
Start winding—14 turns of one No. 30 (.0100 in.) d.s.c. wire. *SF* equals 12.
Turns per pole—168 for starting and 400 for main or running winding. Starting turns 42 per cent of running turns.
Running and starting windings skein-wound. Series connection used.

Winding No. 2—For 1/12-hp., 110-volt, 60-cycle, 1,725-r.p.m., four-pole motor, 24 slots, 2¾-bore, 1⅜ long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Main winding	1/1	2	1		1	2	1/1	2	1		1	2	1/1
Start winding				1/1	2				2	1/1			

Main winding—40 turns of one No. 23 (.0226 in.) d.s.c. wire. *SF* equals 8.
Start winding—25 turns of one No. 27 (.0142 in.) d.s.c. wire. *SF* equals 6.
Turns per pole—320 main and 150 starting. Starting turns 47 per cent of running turns. Both windings skein-wound. Series connection.

Winding No. 3—For 1/6-hp., 110-volt, 3,400-r.p.m., 60-cycle, two-pole motor, 3.6-amp., 24 slots, 3-in. bore, 1½ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Main winding	1	1	1	1	1			1	1	1	1	1						
Start winding							1	1	1	1				1	1	1	1	1

Main winding—36 turns of one No. 16 (.0508 in.) d.c.c. wire. *SF* equals 10.
Start winding—30 turns of one No. 27 (.0142 in.) d.s.c. wire. *SF* equals 10.
Turns per pole—360 main and 300 starting winding. Starting turns 83 per cent of running turns. Both windings split skein-wound. Series connection.

Winding No. 4—For 1/6-hp., 110/220-volt, 1,725-r.p.m., 60-cycle, four-pole motor, 24 slots, 3⅛-in. bore, 1⅝ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Main winding	1/1	2	1		1	2	1/1	2	1		1	2	1/1
Start winding				1/1	2				2	1/1			

Main winding—46 turns of one No. 22 (.0254 in.) d.c.c. wire. *SF* equals 8.
Start winding—34 turns of one No. 28 (.0126 in.) d.s.c. wire. *SF* equals 6.
Turns per pole—368 main and 204 starting winding. Starting turns 56 per cent of running turns.
Both windings skein-wound. Series connection for 220 volts and two-parallel for 110 volts.

Winding No. 5—For 1/6-hp., 220-volt, 1.9-amp., 1,725-r.p.m., 60-cycle, four-pole motor, 36 slots, 3¾-in. bore, 1½ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Main winding	1/1	2	2	1			1	2	2	1/1	2	2	1			1	2	2	1/1
Start winding						1	1						1	1					

Main winding—36 turns of one No. 22 (.0254 in.) d.s.c. wire. *SF* equals 12.
Start winding—61 turns of one No. 26 (0.159 in.) d.s.c. wire. *SF* equals 4.
Turns per pole—432 main and 244 starting. Starting turns 56 per cent of running turns.
Both windings skein-wound. Series connection.

Winding No. 6—For 1/6-hp., 220-volt, 60-cycle, 2.2-amp., 1,725-r.p.m., four-pole motor, 36 slots, 3½-in. bore, 1⅝ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Main winding	2	2	1			1	2	2		2	2	1			1	2	2	
Start winding				2	2				4				2	2				4

Main winding—37 turns of one No. 20 (.032 in.) d.s.c. wire. *SF* equals 10.
Start winding—32 turns of one No. 28 (.0126 in.) d.s.c. wire. *SF* equals 8.
Turns per pole—370 main and 256 starting. Starting turns 69 per cent of running turns.
Both windings skein-wound. Series connection.

After finding the size of wire from the above data, and after the turns per slot and size of wire for the starting winding have been determined, it is a good plan to try the total number of wires in one slot, that is, the total number of running and starting wires, and if possible increase the running winding wire one size. In case the starting winding wires make the slot full and tight, the starting winding wire size can be reduced one size without bad effects so as to give a liberal size for the running winding. This completes the necessary data for figuring out the running winding.

The starting windings of split-phase motors are designed to give phase displacement. This is accomplished by making the resistance of the starting winding high as compared to the resistance of the running winding. The resistance of the starting winding is proportioned so as to limit the starting current to 4 to 6 times the current that is taken at full load.

However, to work out the starting winding by the resistance method calls for calculations that are likely to cause mistakes. It is safer to use known values taken from good existing windings, such as in the windings given in Table II, and then calculate the starting winding data by percentages based on the turns per pole of the running winding, as there is less likelihood of making annoying mistakes.

In the tabulated windings Nos. 1 to 14 the percentage of starting winding turns per pole to the running winding turns per pole has been given in each case. On an average, the turns per pole for the starting winding can be considered as 62 per cent of the running winding turns per pole. Or if any winding that is being worked out checks up with any one of the typical windings, the starting winding data can be taken directly from the tabulated winding data with good results. From 50 to 65 per cent of the running winding turns can be safely used for the turns per pole for the starting winding and a satisfactory winding will result.

The next step in laying out the starting winding is to determine the size of wire. This can also be done by using the running winding as a base. From the windings given in Table II it will be found that for four-pole motors the size of wire for the starting winding runs from four to eight sizes smaller than the running winding, or that on an average the starting winding wire size can be made six or seven sizes smaller than the running winding wire size. Then for a two-pole motor winding, the starting wire will be 11 sizes smaller than the wire used in the running winding. For

Table II—Winding Data for Fourteen Typical Single-Phase Motors Designed for 60-Cycle Circuits

(Continued from the preceding page)

Winding No. 7—For ⅛-hp., 110/220-volt., 2.5/1.25-amp., 60-cycle, 1,725-r.p.m., four-pole motor, 24 slots 3⅛-in. bore, 1¼ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Main winding	1/1	2	1		1	2	1/1	2	1		1	2	1/1
Start winding				1/1	2				2	1/1			

Main winding—70 turns of one No. 23 (.0226 in.) d.c.c. wire. *SF* equals 8.
Start winding—58 turns of one No. 30 (.0100 in.) d.s.c. wire. *SF* equals 6.
Turns per pole—560 main and 464 starting. Starting turns 82 per cent of running turns.
Both windings split-skein. Series connection for 220 volts and two-parallel for 110 volts.

Winding No. 8—For ⅛-hp., 220-volt, 60-cycle, 1,750-r.p.m., four-pole motor, 24 slots, 3-in. bore, 2 in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Main winding	1/1	2	2		2	2	1/1	2	2		2	2	1/1
Start winding				2/2	1	1		1	1	2/2			

Main winding—44 turns of one No. 22 (.0254 in.) d.s.c. wire. *SF* equals 10.
Start winding—38 turns of one No. 29 (.0113 in.) d.s.c. wire. *SF* equals 8.
Turns per pole—440 main and 304 starting. Starting turns 70 per cent of running turns.
Both windings skein-wound. Series connection.

Winding No. 9—For ¼-hp., 110-volt, 60-cycle, 3,400-r.p.m., two-pole motor, 24 slots, 3¼-in. bore, 1⅞ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Main winding	1	1	1	1	1			1	1	1	1	1						
Start winding							1	1	1	1	1			1	1	1	1	1

Main winding—64 turns of one No. 18 (.0403 in.) d.c.c. wire. *SF* equals 10.
Start winding—59 turns of one No. 30 (.0100 in.) d.s.c. wire. *SF* equals 10.
Both windings split skein-wound. Two-parallel connection.
Turns per pole—640 main and 590 starting. Starting turns 90 per cent of running turns.

Winding No. 10—For ¼-hp., 110-volt, 4.18-amp., 1,725-r.p.m., four-pole motor, 36 slots, 3⅝-in. bore, 1½ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Main Winding	1/1	2	2	1			1	2	2	1/1	2	2	1			1	2	2	1/1
Start winding						2	1						1	2					

Main winding—37 turns of one No. 21 (.0285 in.) d.s.c. wire. *SF* equals 12.
Start winding—45 turns of one No. 26 (.0159 in.) d.s.c. wire. *SF* equals 6.
Turns per pole—444 main and 270 starting. Starting turns 60 per cent of running turns.
Both windings skein-wound. Two-parallel connection.

Winding No. 11—For ¼-hp., 110-volt, 1,700-r.p.m., 60-cycle, four-pole motor, 48 slots, 4-in. bore, 2 in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Main winding	1/1	2	2	1				1	2	2	2	1/1	2	2	2	1				1	2	2	2	1/1
Start winding						1/1	1	1									1	1	1/1					

Main winding—19 turns of one No. 19 (.0359 in.) d.s.c. wire. *SF* equals 16.
Start winding—30 turns of one No. 26 (.0159 in.) d.s.c. wire. *SF* equals 6.
Turns per pole—304 main and 180 starting. Starting turns 60 per cent of running turns.
Main winding hand-wound. Two-parallel connection.

Winding No. 12—For 1/3-hp., 110-volt, 1,725-r.p.m., 5.3-amp., 60-cycle, four-pole motor, 36 slots, 3⅞-in. bore, 2⅛ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Main winding	1/1	2	2	1			1	2	2	1/1	2	2	1			1	2	2	1/1
Start winding						2	1						1	2					

Main winding—32 turns of one No. 20 (.032 in.) d.c.c. wire. *SF* equals 12.
Start winding—43 turns of one No. 26 (.0159 in.) d.s.c. wire. *SF* equals 6.
Turns per pole—384 main and 258 starting. Starting turns 67 per cent of running turns.
Main winding hand-wound. Two-parallel connection.

Table II—Winding Data for Fourteen Typical Single-Phase Motors Designed for 60-Cycle Circuits

(Continued from the preceding page)

Winding No. 13—For ½-hp., 110-volt, 1,750-r.p.m., 60-cycle, four-pole motor, 48 slots, 6⅜-in. bore, 2½ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Main winding	1/1	2	2	2	1				1	2	2	2	1/1	2	2	2	1				1	2	2	2	1/1
Start winding							1/1	2	1								1	2	1/1						

Main winding—9 turns of one No. 14 d.c.c. wire. *SF* equals 16.
Starting winding—6 turns of one No. 23 d.c.c. wire. *SF* equals 12.
Turns per pole—144 main and 72 starting. Starting turns 50 per cent of running turns.
Both windings hand-wound. Parallel connection. Windings on rotor.

Winding No. 14—For 1-hp., 110/220-volt, 14.4/7.4-amp., 60-cycle, 1,740-r.p.m., four-pole motor, 48 slots, 5¼-in. bore, 2½ in. long.

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Main winding	1/1	2	2	2	1				1	2	2	2	1/1	2	2	2	1				1	2	2	2	1/1
Start winding							1/1	2	1									1	2	1/1					

Main winding—14 turns of two No. 18 d.c.c. wires in parallel. *SF* equals 16.
Start winding—18 turns of one No. 26 d.c.c. wire. *SF* equals 8.
Turns per pole—224 main and 144 starting. Starting turns 64 per cent of running turns.
Main winding hand-wound. Starting winding skein-wound. Connection: series for 220 volts and two-parallel for 110 volts.

two-pole windings, the turns per pole for the starting winding should not be less than 80 per cent of the running winding turns per pole.

For the starting winding, the turns per skein or per slot are found in the same way as already explained for the running winding.

By following out the methods explained in this article and studying the steps very closely, it will be found possible to take a three-phase or a two-phase core and calculate for it a single-phase winding that will give good results. On the other hand, a new winding can be worked out for a single-phase motor even when the original winding data are not known; or a starting winding can be designed for use with any main winding that may still be intact and in satisfactory condition.

Equipment Used to Apply Lubricants

(Continued from page 218)

turbines and other high-speed devices, and for similar applications. In some closed systems the bearings or gear faces are flooded with oil which not only lubricates but cools the bearing.

The lubricating systems mentioned above are typical in a general way of the various types of devices available. No attempt has been made to describe in detail the many common types of equipment coming under the first and second classifications previously mentioned.

The choice of a method of applying lubricant is dependent upon the type of lubricant used, the service and operating conditions, and the type of bearing.

From the descriptions which have been given of lubricating equipment, and an intimate knowledge of the operating and service conditions in their plants, it is hoped that industrial operating men may receive assistance in solving their lubrication problems. The manufacturer is always willing to give further advice or explanations in the application of his equipment to a particular problem encountered in the lubrication of industrial equipment.

The lubrication of motors will be discussed in an article which will appear in an early issue.

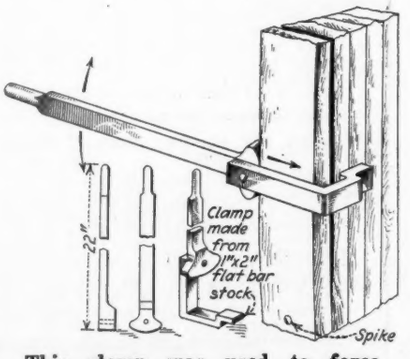
EDITOR'S NOTE: Special acknowledgment is made to the following companies for assistance in the preparation of this and previous articles: Adams Grease Gun Corp., New York City; Bassick Mfg. Co., Chicago, Ill.; Bowen Products Corp., Auburn Div., Auburn, N. Y.; Carr Fastener Co., Cambridge, Mass.; Dearborn Chemical Co., Chicago, Ill.; Dixon Crucible Co., Jersey City, N. J.; Gits Bros. Mfg. Co., Chicago, Ill.; Hunter Pressed Steel Co., Landsdale, Pa.; Keystone Lubricating Co., Philadelphia, Pa.; Kelly Lubricator Co., Syracuse, N. Y.; Madison-Kipp Corp., Madison, Wis.; Marland Refining Co., Ponca City, Okla.; McCord Radiator & Mfg. Co., Detroit, Mich.; Wm. W. Nugent & Co., Chicago, Ill.; Ohio Injector Co., Wadsworth, Ohio; The Pennzoil Co., Oil City, Pa.; Standard Oil Co. of Ind., Chicago, Ill.; Superior Flake Graphite Co., Chicago, Ill.; The Texas Co., New York City; Vacuum Oil Co., New York City; Waverly Oil Works Co., Pittsburgh, Pa.

Clamp for Straightening Planks in Laminated Wall

A TYPE of a carpenter's clamp, which was used successfully to bend 2-in. by 6-in. planking edgewise in the construction of a sawdust fuel bin, is shown in an accompanying illustration.

The bin was constructed of 2-in. by 6-in. planks laid and nailed flat against each other, thus forming a laminated wall 6 in. thick. As some of the pieces were "snaky" some means of straightening them was necessary to make the wall smooth. The clamp shown in the sketches was made of 1-in. by 2-in. flat iron. The lever was 22 in. long and was made double thick on the working end which was rounded with a large radius to present a large bearing surface to the wood. The lever was fastened to the clamp with a ½-in. rivet.

The perspective drawing shows the clamp in operation. The lever may be moved in either direction according to the curved arrows. The head of the lever acts as a cam and forces the plank over in the direction of the solid arrow. This device could be used on either side of the bin to force the planks into position before nailing. Planks with considerable curve were nailed on with the curve in one extending to the right and in the other to the left, so that they would compensate each other.

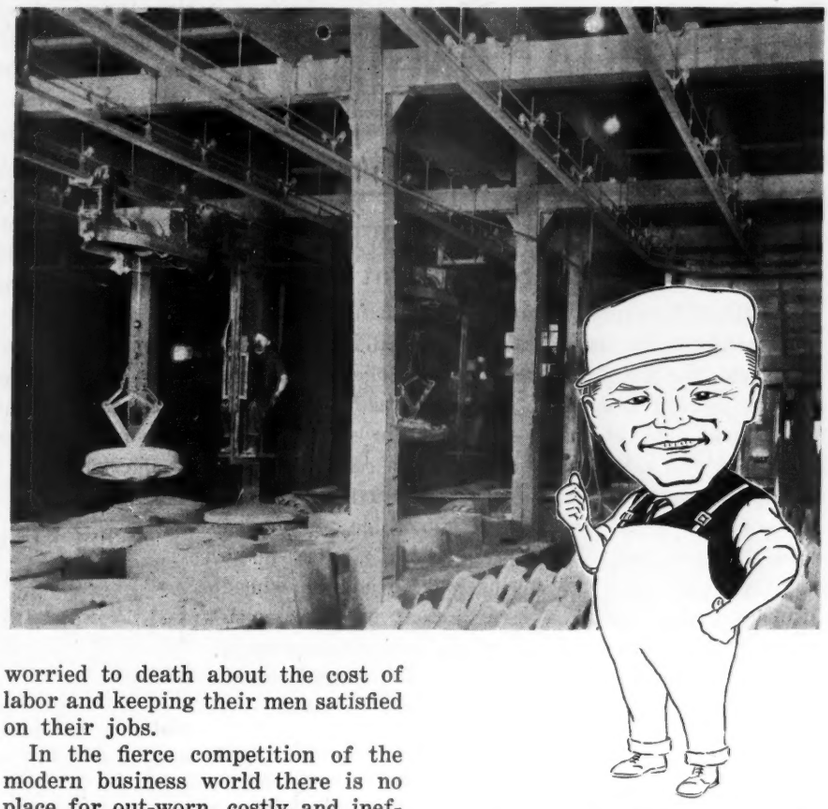


This clamp was used to force crooked planks in line when building up a laminated wall for a sawdust fuel bin.

W. L. STEVENS.
New Westminster, B. C., Can.

Lift and Carry Operations

can never be eliminated but they need not be the meanest jobs in your plant



STUDIES in production costs have worked great changes in handling operations in the up-to-date plants of today. The age of main strength and awkwardness in moving raw materials and semi-finished parts to and from machines has passed, and in its place can be found the results of brain work in speeding up operations and making handling jobs less dependent on a strong back and good right arm. The work expected nowadays from the day laborer, and the basis of his wage, is more on how he uses his head than his muscle; and so the many men who were once classified as day laborers are now expert machine operators who are happy and contented in doing their work, for which they receive a greater rate of pay, with less physical exertion, than was the case a comparatively few years ago.

One good example of this application of brain power to mechanical handling is shown in the accompanying picture, which shows two men handling awkward work. Under any other circumstances this would not be considered an attractive job and would call for a gang of men with a necessary supervisor to direct their operations. This picture plainly shows how the thinking of the individual responsible for the installation of this tramrail and hoist system effectively provided all necessary supervision of what to do and where to go in a simple mechanism that ordinary intelligence can learn to operate. The results are not hard to imagine in the speeding up of a hard job and making it attractive enough so that the hiring and firing of men to do the work is a problem that has almost been forgotten, as a thing of the past.

Such lift-and-carry systems are somewhat new to industry, but they have made such progress that today the plant that does not use them is among those that are struggling against competitive conditions and worried to death about the cost of labor and keeping their men satisfied on their jobs.

In the fierce competition of the modern business world there is no place for out-worn, costly and inefficient methods that may have been good enough in their time, and under different conditions than exist today, but which have been left behind in the swift march of industrial progress.

Strictly aside from the actual economies possible through the use of this equipment and the nice return that it will earn on the small amount of money it costs, I am calling this matter to your attention as a study in the handling of men. No plant superintendent or general foreman can afford to allow good, hard-working men to leave him after years of service and training simply because other plants provide easier work at the same rate of pay. The training of men is an expensive operation and it is worth something to keep them satisfied and happy on their jobs. Loyalty and a contented mind devoted to an honest day's work will always be reflected in the quality of product turned out and the cost of making it. But too often competitive conditions are blamed for fewer orders and less work in the plant, when a little time spent in studying hard jobs will disclose that the real trouble can be eliminated by reductions in production costs and the elimination of wasted time in back-breaking work that lift-and-carry systems can perform tirelessly and at insignificantly small cost.

As a superintendent you may be so close to your production problems that you are like the proverbial woodman who could never see the extent of the forest because of the trees. If you are in the midst of things so much every day that you are worried to death about plant production delays and slow deliveries, just take a vacation and visit some of the larger and newer plants where a new picture of production economies will come to you and you will go home and be able to show this to your boss in the light that will enable you to secure an authorization to make the needed changes in your plant to eliminate production worries. If you have to pay your own expenses on such a trip it will pay you in the end to do so, for you will get it all back some day in the reward that always comes to those who know how to relieve the boss of high operating costs and make business easier to get at a profit. After all this is as much a part of your job as making a good automobile, a good steam engine, a good monkey wrench or a good anything else.

Practical Pete

INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

G. A. VAN BRUNT, *Managing Editor*

Do Not Forget the Days When You Were Starting Out

PROBABLY every industrial operating executive remembers the days when he started in the plant, either as "the kid," or directly from college to apply his engineering training. In either case he can, no doubt, look back at many rebuffs from some of his associates, and also carries appreciative remembrances of helpful suggestions and encouragement from others.

Frequently it is too late or impossible to reward those who assisted. However, practically every plant has its "kid" or new engineering graduate whose future is influenced to a large extent by those with whom he associates. Kind words and deeds cannot always be paid back, but they can be passed on to others who will appreciate and be helped by them.

Reduction of Factory Noise Is an Aid to Production and Employee Comfort

THE interest taken in employee welfare in the more progressive industrial plants is remarkable. This interest takes the form of improving the working conditions through making the surroundings more pleasant, providing better lunch rooms, recreation facilities and numerous other advantages. There is one thing, however, that is not receiving the attention that it should and which of all things has a great deal to do with the subconscious or nervous tension under which the employee works. We refer to noise.

There are many industrial processes where noise is unavoidable—forging, for instance, or the din found in a tack factory. On the other hand, there are noises that can be avoided. One of these is the annoying whine from a chain drive, which is due to no fault of the chain itself but is caused purely by maladjustment or faulty installation. Another noise is the nerve-racking din caused by poorly-aligned gears and pinions. Proper and periodic maintenance will reduce this greatly and the use of non-metallic gears will in many instances eradicate the troublesome noise. Another noise that is particularly distressing is that caused by whistles of high-pitch tone, such as found on yard switching locomotives, warning and mill signal whistles, call systems, and the like.

A high-pitch whistle that is sounded at frequent intervals causes a nervous tension that is not conducive to careful workmanship, while if the whistle is sounded at infrequent intervals, the nervous shock caused by the sudden blast is particularly trying. Use of low-pitch whistles will eliminate the nerve shock and at the same time the sound will carry further. If a low-pitch whistle is not desired, use may be made of some of the many types of electrically-operated automobile and signal horns now on the market. Also, some attention should be paid to the question of how far the sound or signal should carry. Only too often are the signals intended for only one department heard by plant departments at a considerable distance away.

Tremendous strides have been made in the use and application of improved factory lighting to eliminate eye strain with its consequent nerve strain and impaired production. Investigate the possibility of decreasing unnecessary and nerve-racking factory noises as a means of increasing the comfort of employees with consequent improvement in the quality and quantity of production.

Good Lighting in an Industrial Plant Costs Less Than Nothing

DURING the past few years the results of investigations have convinced the lighting expert that poor lighting is costly. He has found this out by proving that good lighting not only costs nothing, but usually yields a handsome profit on the investment. Those who are familiar with the manifold details of the scientific aspects of lighting and vision have predicted for many years that adequate and proper lighting would be very profitable to everyone.

The average intensity of illumination outdoors, under which our visual apparatus evolved, is a thousand times greater than the intensities commonly encountered indoors. There is every indication that illumination intensities upon our work-places and the brightness of the work are such that the eye is working in "low" instead of in "high," as it should for continuous use. The ability to see fine detail, distinguish differences in brightness, discriminate color contrasts, see quickly and accurately, work with safety, and keep up our spirits, increases as the intensity of illumination increases. Scientists know that this increase usually continues far beyond any intensities of illumination now provided by artificial lighting. Furthermore, light is so generally misused that visibility is decreased due to glare, shadows, great brightness-contrasts, reflected images of the light sources, and so on.

Investigations of the influence of lighting upon production in factories measure the combined effect of all these factors. Many investigations of this phase of production have shown an appreciable increase in production under improved lighting. Usually this increase is at least several times greater than the cost of the better lighting, which averages only 1 or 2 per cent of the payroll. Thus by placing good lighting on the payroll, it is safe to predict that it will always pay for itself and usually will net a profit of several hundred per cent.

Lighting experts claim that there are very few factories in the world in which improved lighting will not at least pay for itself.

Rules for the Safe Operation of Overhead Traveling Cranes

"SAFETY FIRST" has become a by-word in all industrial plants and careful investigations have discovered and eliminated many unsafe practices as a result. Even so, there is much to be done in the case of the overhead traveling crane.

The traveling crane is a source of accidents not only because the crane presents a hazard to those working underneath but also because it must be maintained, repaired, and operated from its overhead location. The overhead crane combines all the hazards of the freight elevator, the elevated electric car, and a railroad, with few of their safeguards. Safety has become more or less standardized for the three types of equipment just mentioned and accidents on them are few and far between. Such, however, is not the case with cranes.

At the present time, the Safety Division of the Association of Iron and Steel Electrical Engineers is collecting the safety rules now in effect in the various steel companies with the hope of formulating a set of safety rules that will cover all phases of the subject and materially aid in promoting safety in the operation of cranes. This action is to be commended and encouraged. It is hoped that the outcome of the work of this Association will be a standardized, working set of rules that may be universally applied to crane operation in all types of industrial works. Such rules are greatly needed and will prove to be of inestimable value.

The Size of the Junk Pile Is a Measure of Progress

DURING an interview reported in a recent issue of *Light*, published by the National Lamp Works of General Electric Company, Samuel Insull, one of the outstanding figures in the central station field, was asked what he considered to be the most valuable asset of the lighting and power industry.

"The junk pile," was his answer. Then he added, in explanation, "The junk pile indicates how quickly an industry can learn."

In these few words Mr. Insull expressed a truth that means a great deal to every industrial plant executive. In far too many industrial plants there are in operation today scores of machines and other equipment that should have been junked long ago. Good in its day—perhaps it was the best that could be had—this equipment is now obsolete and inefficient, a potential source of trouble from breakdowns, and a hindrance to maximum production. Methods and processes that have been discarded by progressive plants, inefficient equipment, and high operating and maintenance costs do not make for high quality and quantity of products, at low unit cost.

Nor is the personal application of this truth hard to make. How many of us are held back from the advancement that we might obtain, by our tenacious adherence to out-worn ideas, antiquated notions and stubborn belief that the way we always have done certain things is necessarily the best way to do them? After all, growth and advancement in a professional and intellectual way are simply the acquisition of new facts and new knowledge, and the discarding of ideas and practices that have been shown to be erroneous or have been superseded by ideas and practices that are better adapted to present-day conditions.

Check over your mental junk pile and see how many additions you have made to it, say, during the past five years. By so doing you may find that you could, with profit, increase the size of that junk pile considerably.

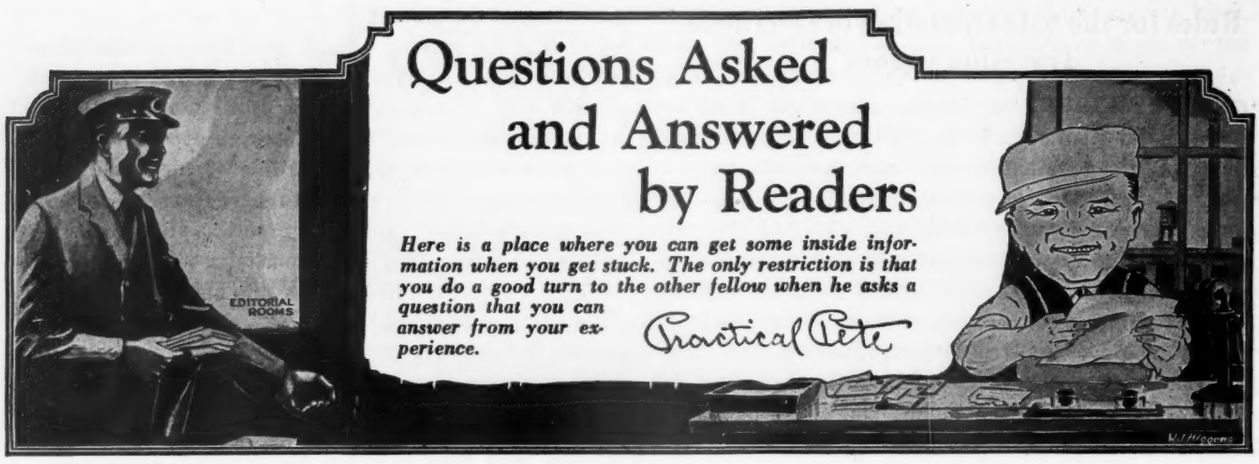
Do Not Let Whims Be Your Guide in Laying Out Power Drives

COWHIDE in the form of leather belting has been with us for a long time. Volumes of engineering data can be found on its use and methods of application, all based on years of performance; and yet there are plenty of improper applications of otherwise good belts in almost any large plant, new or old, that you may visit today. You will find too long centers, too short centers, wrong pulley ratios, wrong belt widths, light-weight belts used where doubles should be used, and large and small doubles with home-made or makeshift belt tighteners and other such contraptions that are evidence of bungled drive design or corrections of mistakes that could have been avoided by the proper use of belt data to be found in any good mechanical engineering handbook.

Because belts have been so generally used and every plant man has taken a hand in applying them according to his own ideas, or according to space restrictions imposed by someone whose power drive knowledge or experience is still in the kindergarten stages, there have sprung up the many cure-alls for belt applications and troubles.

We hold no particular brief for the leather belt, simply because it needs no defender. It has made a place for itself through years of service under favorable and unfavorable conditions, and although the whims of drive designers to do away with belts must be expected to come and go in the future as they have in the past few years, the belt drive will be with us for a long time to come, simply because there is a limit to complications in machine drives, so that cost alone and the competition and simplicity of a well-laid-out belt drive will be the deciding factors.

To our readers who are responsible for plant operating costs, we offer the suggestion that a few hours' study of such data on belt and power drives as are contained in Kent or Marks or any other good handbook will provide plenty of food for thought on how to save money in their own plants. Belt slip, belt stretch and the burning of belts over driving pulleys have reasons for which ignorance and belt dressing are not the corrective remedies.


EDITORIAL ROOMS
Questions Asked and Answered by Readers
Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.
Practical Pete

Who Can Answer These?

Wiping Lead Joints in Lead-Sheath Cable.—I should like to have readers give me some information on how to go about wiping joints in lead-covered, three-conductor, 2,300-volt cable. I should like to know how to prepare the joint for wiping, what materials should be used, how to wipe the joint, and any precautions that should be observed in wiping the joint.
Benoit, Ala. G. E. W.

* * * *

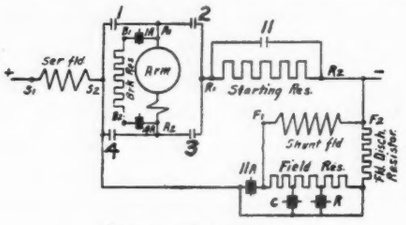
Demagnetizing a Lathe.—I have a 24-in. by 10-in. selective head lathe, which is magnetized; at least, when any work is done on the lathe, the chips cause us trouble by sticking to the lathe tool and surrounding lathe parts. It is my opinion that the spindle of the lathe is magnetized. I shall greatly appreciate it if readers will tell me how to demagnetize this lathe. If it is necessary to use a demagnetizing coil, how big should the coil be, how many turns and what size of wire should be used? Also, how many amperes should flow through the coil? Is there any way that I can demagnetize this lathe without using a demagnetizing coil?
Beaumont, Tex. O. C. B.

* * * *

Best Way to Install Ball Bearings in Lineshaft Hangers.—We are going to replace the split, babbitted, shaft-hanger bearings on a $2\frac{7}{16}$-in., 72-ft. shaft with new ball bearings. The same drop hangers are to be used. Two solid pulleys are used; the remainder are split, either wood or steel. The shafts are connected with keyed flange couplings. What is the best way to go about making the change? Would it be best to let the shaft down to the floor, or work overhead? What is the easiest way of getting the flanges off and on again? Would it be better to replace them with compression couplings?
Syracuse, N. Y. H. L. G.

* * * *

Changing Control to Obtain Lower Motor Speed.—The motor on our reversing planer drive is a 10-hp., Westinghouse, frame 90, type SK, shunt-wound motor having a speed range of 250 to 1,000 r.p.m. We have no spare for this motor and when it fails, it is necessary to substitute a 15-hp., 400/1,600-r.p.m., type SK Westinghouse, shunt-wound motor. The automatic control on the planer drive is arranged as shown in the accompanying diagram. The sequence of operation of the contactors is shown in the table. In this tabulation the number of the contactor is given in the left-hand column, the "Cut" column refers to the cut stroke, the "Return" column refers to the return stroke, and the "Bk." column refers to the dynamic braking applied between reversals. The control is arranged so that a low speed is used on the cutting stroke and a high speed on the return stroke. These speeds are obtained by proper adjustment of the shunt-field rheostat. When using the 400/1,600-r.p.m., 15-hp. motor, the speed of the return stroke can be properly adjusted, but the cutting stroke is too fast. Full field on the motor gives 400 r.p.m., whereas a speed of approximately 300 r.p.m. is



Sequence of Contactors

Con.	Cut	Bk.	Off	Bk.	Return
1					○○
2	○○				
3					○○
4	○○				
11	○				○
1A	○○	○	○	○	
4A		○	○	○	◎◎
HA	○	○	○	○	○

desired. Can readers tell me any way that I can obtain this speed on the 15-hp. motor without rewinding it or changing its fields? Is it possible to obtain satisfactory results with resistance in series or in parallel with the armature? If so how much resistance should be used, or how should I go about determining the correct amount?
Indiana Harbor, Ind. A. R. D.

* * * *

Method of Connecting Generator to Bus.—In the power house of our lumber mills we are planning on installing a 6,000-kw. three-phase, 480-volt, 9,000-amp. turbo-generator. To the bus there are now connected an 800-kw. and a 2,000-kw., 480-volt generator. I would like to know what readers would recommend for connecting the 6,000-kw. generator to the bus. Should cable be used, and if so, how should it be arranged so as to eliminate the inductive effect and its consequent heating due to the heavy current flowing? Would it be better to use bus-bars and if so, how should they be supported and arranged so as to reduce the induction? Any recommendation that readers can give for the layout of the connection between the generator and bus will be appreciated.
Bellingham, Wash. E. M. D.

* * * *

Changing Wire Insulation.—I am planning to rewind the armature of an Autolite generator. This armature was originally wound with No. 18 single-cotton-covered wire. Can some of the readers of this column inform me what results I will get if I rewind this armature with No. 18 enameled wire? I shall be grateful for your help.
Marietta, Ohio. E. L. W.

Proper Foundation for Alternator.—(1) We are going to install a 133-kva., belt-driven alternator in the near future, and I should like to know how to make a suitable foundation for it. We are thinking of using a wooden framework. Is this alternator too large for such a foundation? I should like to know what type of foundation readers would recommend for this alternator, and also how the foundation should be made. (2) When the distance between pulley centers of the alternator and engine is long should the alternator foundation be heavier than when the machines are close together? How should the alternator be fastened to the timbers or other types of foundations that are recommended? I shall greatly appreciate any information that readers can give.
New Orleans, La. O. C. H.

* * * *

Trouble From Static on Belt-Driven Machines.—We have about 200 sewing machines all of which are belt driven. The girls who run these machines complain that they frequently get shocks from them. I believe that this is due to static from the leather belts which drive the sewing machines. I shall appreciate it very much if some reader can tell me how to prevent this trouble. I have grounded the sewing machines but the trouble still continues. To what should I ground the machines so as to obtain the best results? How should the ground be made? I might say that the sewing machines are placed on wood floors in a room that is quite dry and warm. Would the use of rubber belts correct the trouble I am encountering? I should like to learn the experience of other readers on this subject.
York, Pa. P. C.

* * * *

Answers Received To Questions Asked

Selecting High-Pressure Bearings.—In one of our manufacturing processes the product is rolled under high pressure. We have always had considerable difficulty with the bearings and as we are going to rebuild the machines are considering installing other types of bearings. I would like to know what types of bearings other operating men favor for paper calendars, rubber mills, and cereal rolls, as I believe our problem is similar. Will some readers from these industries please give me their experience with babbitt (including the type), bronze bushings, ball or roller bearings and the method of lubrication which they have found most satisfactory?
Brooklyn, N. Y. J. A. A.

A high-pressure bearing of the type J. A. A. is considering should be of a design to provide automatic lubrication, and of such proportions that the pressure per square inch of projected area is within the limit of the load-carrying capacity of the bearing metal.

The bearing metal should be softer than the metal of the journal so that a minimum of injury would result from seizing. Other desirable properties are: a low co-efficient of friction, a low co-efficient of expansion, high heat conductivity, the property of adhesion, to hold the oil film, the ability to carry intermittent overloads, and the ability to withstand abnormal bearing temperatures. The soft alloy bearing metals yield to the contour of the journal under heavy loads and increased temperatures, which decreases the pressure on the high spots, re-establishes the oil films and so prevents the seizing of the journal. The harder metals, such as bronze and brass, according to my experience, do not have these advantages or possess the most desirable characteristics mentioned.

Genuine babbitt has been used successfully for heavy duty in properly-designed bearings, but I have found under test and actual working conditions in the field that a similar white metal known as Bearite, which is manufactured by the A. W. Cadman Co., is an exceptional bearing metal. This metal can be used in bearings with pressures from 150 lb. to 300 lb. per inch of projected area, with corresponding temperature rises of 70 and 130 deg. F. respectively in the bearing, with peripheral journal speeds of 300 to 1,100 f.p.m.

In the absence of definite data as to speed, load, physical limitations, and the nature of service, no definite proportions or design can be given to J. A. A. The length of the bearing in terms of the diameter, varies according to the nature of the load and the type of bearing. For heavy journals with fixed bearings, the length is from two to three times the diameter of the journal.

E. H. LAABS.
Engineer,
The Cutler-Hammer Mfg. Co.,
Milwaukee, Wis.

* * * *

Misleading Results Sometimes Obtained from Magneto Test.—Sometimes I get rather misleading results through the use of a magneto to determine whether there are defects in some of our electrical apparatus. Under certain conditions I have found that the magneto will indicate a dead ground, whereas further investigation shows that the equipment is in very good operating condition. Also, I have found that a magneto will sometimes indicate an open in a shunt-field coil, when further investigation shows that the field coil is O. K. I should like to know if any readers have had similar experiences and can explain the reasons for this peculiar action of the magneto. Also, can you suggest other test methods that might be used under the conditions mentioned?

Omaha, Neb. M. P.

In answer to the question asked by M. P., I have found that the use of a magneto for testing is not advisable in a number of instances. With the exception of a few special types, the magneto generates an alternating current. When used in testing a shunt field, or any highly inductive winding, the choking effect of the inductance limits the current to less than that required to ring the magneto bell. This will cause the magneto to indicate an open circuit when the circuit is closed. When testing a line for grounds the capacity of a long line is often so great that the charging current will be sufficient to ring the magneto bell, indicating a ground when the line is actually clear.

An instrument that I find very handy for making a number of different tests is a Weston, model 45, direct-current voltmeter, having four ranges, 3, 15, 150 and 300 volts. This instrument is very sensitive, having a resistance of 108.38 ohms per volt. It is shielded against stray magnetic fields by an iron case which is enclosed in a substantial wood carrying case, making a very rugged instrument that will stand a lot of external abuse.

In testing for grounds or opens, I use the 3-volt range and two dry cells. This will give a positive indication through a fairly high resistance. The deflection of the pointer of the meter when connected through a resistance of 50,000 ohms is about one scale division. With a lower resistance you get a correspondingly greater deflection. In case of an open, the voltmeter will give no deflection; that is, zero voltage. In case of a short or dead ground, the voltmeter will indicate full battery voltage or 3 volts.

By using the voltmeter method of measuring insulation resistance, measurements of insulation resistance can be made up to as high as 9 megohms when using the 300-volt range on the voltmeter and a 220-volt power supply. In making insulation tests where direct-current power supply line is not available, I have five of the small size 22½ volt, radio B batteries mounted in a carrying case. This gives me about 110 volts. These batteries can be purchased for about 65c each and with reasonable care will last a year or more. Using this set of batteries and the 150-volt range on the voltmeter, a deflection of one scale division will read 1.8 megohms.

By using the various ranges of this instrument and a corresponding voltage, resistance can be measured fairly accurately down to about 10 ohms. This instrument is also useful in testing armatures for opens, shorts or grounds, for checking sets of shunt coils for partial short-circuits, and in setting brushes. It is also useful in testing the voltage of individual cells or groups of cells of storage batteries.

WM. H. FREDRICKSON.
Elizabeth, N. J.

* * * *

Regarding the misleading results obtained by M. P. in his magneto test, I would say that a magneto should not be used for testing for grounds on large coils, on long cable circuits, or between circuits of large electrostatic capacity, because of the condenser effect, which may indicate a physical connection where none but a condenser connection exists. A lamp test using alternating-current supply, the telephone receiver test, and the voltmeter test where the voltmeter is used on alternating current, all have limitations similar to those of the magneto.

In testing for a continuous circuit in a field coil, a telephone receiver in series with a worn-out flashlight cell will give a good, live click when placed across the terminals of the coil under suspicion, if the circuit is not open. Also, in ordinary cases, the lamp test is reliable where the coils do not have too high resistance.

For ground tests, my experience as a trouble man during years of attention to details, leads me to state that for practically all ordinary cases, the voltmeter test for grounds is reliable, when direct-current supply is used for testing instead of alternating current.

Windsor, Canada. L. L. FARRAR.

* * * *

The use of a magneto in testing electrical apparatus should be carried out with caution. This is due to the fact that the magneto generates alternating current and is subject, therefore, to the effect of inductance and capacity in the windings. For instance, if there is considerable capacity between windings and ground, sufficient current will flow in the circuit (made up of one terminal of the apparatus and the other connected to the frame of machine) to cause the magneto bell to give a slight ring and apparently indicate to the tester that a ground exists. This is an alternating-current phenomenon which is readily observed in power transmission circuits where ammeters will give a reading at the generating station even though the circuit is open at the receiving end of the line. This current is commonly known as charging current.

It is often found in trying to ring through a highly inductive winding, that is, one of many turns, as a high-voltage winding on a transformer, that the magneto bell will not ring; this remark is also applicable to a shunt-field coil. This is due to the fact that the impedance of the winding is so high that the magneto generator is not capable of forcing sufficient current through the winding to allow the bell to ring. In other words, to an inexperienced tester an open circuit would apparently exist when the circuit was actually intact.

There are several methods of testing that may be used, all of which are based on using direct current in some way. The following methods are in common use: (1) An outfit consisting of dry batteries and a bell or buzzer. (2) A test set consisting of dry batteries and some form of commercial galvanometer. (3) A lamp bank. (4) A Megger testing set.

Methods 1, 2, and 3 are in common use. The exact number of batteries required for the first two methods, of course, depends on the type of equipment being tested. A number of commercial forms of galvanometers can be purchased on the open market in various forms and under various trade names. The use of a megger outfit for general testing is becoming very common, as the outfit may be adjusted to suit various conditions. In general it may be said that methods 2, 3, and 4 are to be preferred since the result or effect may be seen by the eye while the effect of method 1 is on the ear, which may be, and usually is, not so sensitive as the eye.

A very delicate test consists in using a telephone headset and a dry battery. This test is used in underground cable

work quite extensively for testing for grounds, short-circuits and continuity. It is necessary, however, that the tester should not be deceived when testing for an open circuit if the circuit has much capacity, since a click may be noted when the circuit is first made, due to the current necessary to charge the system. A little practice, however, will overcome the objection to this method which is readily applied and requires very little equipment for using it. C. OTTO VON DANNENBERG.
Designing Engineer,
Sanderson & Porter,
Springdale, Pa.

* * * *

The problem on the action of a magneto, given by M. P., could be answered more completely if the resistance of the ringer were known, and also the types and voltages of the coils and equipment being tested.

Magnetos will often give misleading results on inductive circuits due to the induction set up in the circuit by the alternating current from the magneto. The induction in the circuit varies with the frequency of the magneto and the current flowing through the circuit under test is governed by the resistance and inductance in the circuit. The faster the magneto is turned, the higher the frequency and inductance become. Even though the voltage of the magneto increases with the speed, the inductance may be great enough to reduce the current.

A low-resistance ringer used for testing requires a higher current than one of high resistance. Testing a high-voltage, high-resistance, field coil with a low-resistance ringer may not permit sufficient current to flow in the circuit to operate the ringer, due to the high inductance and resistance in the coil retarding the current. Yet, this same coil tested with a high-resistance ringer may pass enough current to operate the ringer with the same voltage and frequency. In this way, an open-circuit may be thought to exist in the coil. A coil with a large number of turns and which has an open circuit may give a ring with a high-resistance test set if the break is near the center of the winding. The condenser effect between the two parts of the winding may pass enough current to operate the ringer.

Making a ground test with a high-resistance magneto may indicate a ground which would not show up on low-resistance testing equipment. The ground may be a high-resistance one and yet pass sufficient current to operate the ringer, but be of too high resistance to pass enough current to burn out on a low-voltage test. Ground tests should be made with a low-resistance device, but a high-resistance test is good also to prove that no kind of ground exists. It is advisable to make a high-resistance ground test on appliances that are to be handled by inexperienced persons, for a current strong enough to be felt may pass through a ground of this nature.

The use of a magneto for testing should be confined to non-inductive circuits, such as resistance units and other apparatus. Coils may be tested with good results by removing them from their cores, since this reduces the inductance and will permit more current to flow through them with the same voltage applied. Windings with iron cores act the same as any a.c. choke coil even though they may be designed for d.c. operation.

The Electric Fault Finder made by The Electric Controller and Mfg. Co., Cleveland, Ohio, gives splendid results for testing all kinds of equipment. It does not use a magneto, thereby doing away with the frequency and induction effects in circuits under test. I have used it in all kinds of tests and find it entirely satisfactory. I also find the Megger to be one of the most reliable testing instruments as it reads directly in ohms which enables the repairman to compare the condition of the coils under test with standards. The "Meg" is advertised on page 98 of the March issue of INDUSTRIAL ENGINEER by James G. Biddle Co., Philadelphia, Pa. M. P. will make no mistake in securing either one of the instruments I have mentioned if he has much testing to do.
Chicago, Ill. CARL G. HOWARD.

* * * *

Replying to M. P.'s question, I quite agree with his remarks about the results he obtained from testing with a magneto. I also notice that in the January, 1926, issue on page 40, R. N. Vining made similar remarks about the magneto in his article on "Method of Testing for Grounds and Faulty Insulation." Since he did not give the reason for the results obtained with a magneto, which M. P. asks about, I will endeavor to answer his questions.

Among available testing apparatus which we may mention beside the magneto are, the telephone receiver and battery, the vibrating bell or buzzer and battery, the test lamp using d. c. or a. c., the voltmeter and ammeter, and test sets put out by various companies. The one which comes to my mind first is that of the Square D Company, which will indicate a value of a. c. or d. c. roughly, up to 600 volts, distinguishing between these currents and doing almost anything except indicating the polarity of d. c. circuits.

In circuits which we are called upon to test there is the quality of resistance which limits the flow of both d. c. and a. c. according to Ohm's law. Also, every commercial circuit possesses in some degree a quality known as inductance. This quality becomes more apparent if the wire of the circuit is wound on a spool or a coil, and is of greatest value when this coil has a core of iron or soft steel as in the case of a field coil of a d. c. machine or the winding of a transformer. As the current changes in value in a circuit having inductance, a counter-emf. is induced in the circuit which prevents the current from flowing as it would in a circuit in which resistance alone is present. In a d. c. circuit, the current is continuous; therefore, inductance does not materially affect a circuit through which a direct current flows. In an a. c. circuit the value of the current is changing constantly as well as reversing in direction so that inductance will have considerable effect.

A magneto is usually able to ring its bell through 25,000 to 40,000 ohms of resistance, but when we test a circuit of high inductance even though the resistance may be very low, especially so in the case of a primary of a transformer or the field coil of a d. c. machine, the bell may not ring due to the fact that the magneto generates alternating current instead of direct current, for the magneto is a two-pole, a. c. generator with permanent magnets to suply the excitation.

The opposite quality to inductance is capacity or condenser effect, which is also present to some degree in all circuits and to a marked degree in any circuit of considerable length. When testing with a magneto on a wire having considerable capacity connected to it, we may obtain a ring, indicating that the circuit is not open. However, when testing the same circuit with a high-resistance, d. c. voltmeter and a voltage of say 110 volts direct current, the voltmeter reading will indicate an open or zero voltage, outside of a "kick" of the pointer when the circuit is first made. If we add to this voltmeter circuit a reversing key, which will put first the positive side and then the negative side of the direct-current supply to the terminal of the insulated wires, we will get a "kick" each time we operate the reversing key and if we do it fast enough, the voltmeter indication will be the same as if a small voltage of varying value were acting on the line under test. What we are doing is actually putting a. c. into the line, or charging and discharging the condenser which the line constitutes.

The magneto, also, will send a current through, or more correctly, will charge and discharge this condenser and when we remember the very small current necessary to ring the bell or buzzer it is evident that it does not take much of a condenser to have an "apparent resistance" below 25,000 or 40,000 ohms, or low enough to give us a signal.

Electrical Foreman, L. E. DUNHAM.
The Sydney E. Junkins Co. B. C. Ltd.,
Vancouver, B. C., Can.

* * * *

In answering the question asked by M. P., it will be interesting for him to know that a magneto test set should never be used for testing field poles of an electric machine, nor any coil having a number of turns of wire wound upon an iron core. Also an electric circuit of great length should not be tested with the magneto. If a circuit of high capacitance is tested with a magneto test set an erroneous indication may be the result, due to the electrostatic capacity of the circuit and the alternating current of the magneto alternately charging the two conductors to positive and negative potentials, causing the bell to ring, and thereby indicating a short-circuit where none exists. The shunt-field coils of a direct-current motor or generator have a high inductance and when testing the coils with the magneto, the bell may not ring, thereby indicating an open circuit, although the circuit may be closed. The reason why the bell does not ring even though the circuit is not open, is

because of the high impedance of the inductive winding of the field coil to the flow of alternating current from the magneto. The result is that not enough current flows through the magneto to ring the bell.

In the absence of a voltmeter or testing transformer, a grounded coil can be located by the lamp test. A 60-watt or larger lamp connected in series with the coils under test, will act as an indicator and also will prevent excessive current flow. To test for grounded coils proceed as follows: Disconnect the machine from the line; connect one side of the line to one terminal of the field coils, then connect the other side of the line to the frame of the machine. If one of the coils is grounded, the lamp will light. The exact coil that is grounded may be located by opening connections between the coils so as to divide them into groups. Each group should then be tested separately for grounds. After the group with the ground has been found, open the connection between each individual coil in this group and test each coil for a ground. By using a testing transformer the exact location of the ground can be located by the smoke, arc, or heating where the ground exists. OVIDE C. HARRIS.
Plant Electrician,
Freiburg Mahogany Co.,
New Orleans, La.

* * * *

Starting Large Induction Motors.—The local power company does not permit the connection of squirrel-cage motors larger than 25-hp. capacity to its line. Above this size a wound-rotor induction motor is required. Such a motor and its control are of necessity more expensive. It is my understanding that some forms of resistance starters for squirrel-cage motors will cause the initial current peak to build up gradually and consequently create no voltage disturbance on the power company's lines. If any readers have used such starters on motors larger than 25 hp., so as to meet the requirements of power companies and have successfully shown them that motors larger than 25 hp. can be started without line disturbance, I would greatly appreciate learning the details of the application. I would also like to learn the motor size, voltage, speed of motor, and type and maker of starter in each case.
Cedar Rapids, Ia. H. P.

H. P. will be able to obtain the data that he wishes regarding the starting of large induction motors, from such companies as the Century Electric Co., St. Louis, Mo., the Wagner Electric Corporation, also of St. Louis, Mo., and the United States Electric Co., Los Angeles, Calif. The Century type AS motor is made in capacities up to 60 hp. while the Wagner type BW is made up to 50 hp.

The Wagner motor has a winding in the rotor that causes the motor to take low starting current. This winding is shorted when the motor comes up to full speed and the motor runs as a squirrel-cage machine. The Century motor is similar to the Wagner type except that it has a buried squirrel-cage winding which does not function until the motor reaches nearly full speed. The United States Electric motor has both windings, but uses a heavier squirrel-cage winding and does not short the wound-rotor winding. Other companies are adopting this latter scheme. These manufacturers will supply for their motors, data as to the starting current at full load, time of acceleration, and the like.
Seattle, Wash. W. MONTELIUS PRICE.

* * * *

Low-Voltage Generator Will Not Excite.—It was necessary to rewind the shunt field coils of a 50-volt generator of very low capacity, which is direct-connected to a small motor having a speed of about 4,000 r.p.m. It is a two-pole machine having 2,000 turns of No. 37 wire in each shunt field coil. When the winding was completed, the machine generated 55 volts satisfactorily. It was then found necessary to reverse the generator position with regard to the motor, which of necessity reversed the direction of rotation; due to this reversal of rotation the residual magnetism of the generator was lost. When I separately excite the shunt fields from a 50-volt, direct-current bus the generator develops its proper voltage. When I reconnect the fields to the armature terminals I get a reading of only 1 volt. I wish some reader would tell me what is wrong and how I can correct this trouble.
Stamford, Conn. W. E. H.

With reference to W. E. H.'s trouble, the diagrams in the accompanying illustration will show what is happening to his machine and how to remedy the trouble he is experiencing with his generator.

Diagram *A* shows the original conditions for a self-excited generator rotating clockwise, having the right-hand brush positive. The curved arrow indicates the direction of rotation of the armature and the straight arrow in the small circle indicates the direction of current flow in the armature of the generator.

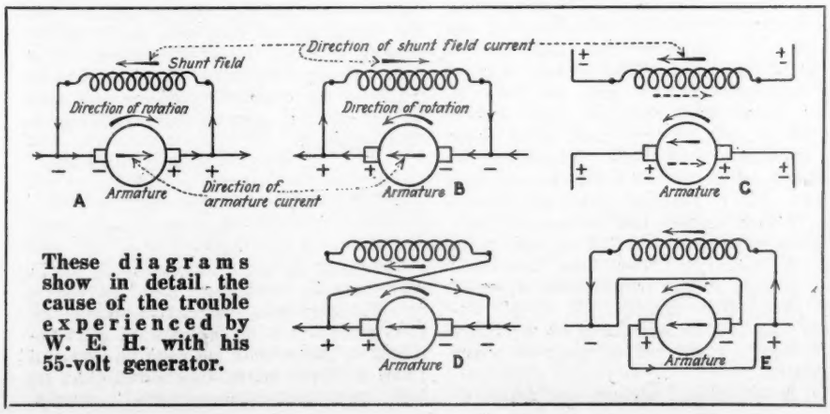
When the direction of rotation of the armature is reversed by turning the generator around 180 deg., this would change the polarity at the brushes, if the field strength could be maintained in its original direction. In diagram *B*, the direction of rotation has been changed to counter-clockwise to correspond with the conditions just stated. This changes the current flow through the armature and also the brush polarity. What happens in this case is that when the generator is started from rest, the pole pieces retain a small amount of residual magnetism of the original polarity and when the armature starts to revolve the residual magnetism generates a current in the armature conductors which flows in the opposite direction to the original current shown in diagram *A*. This results in the armature generating a voltage of the opposite polarity and inasmuch as the fields are connected directly across the armature, the reversal of polarity causes the field current to flow in the opposite direction through the field coils. This current tends to build up the field in the opposite direction and the result is that the magnetomotive force caused by the field current opposes the residual magnetomotive force so that the sum total is zero, the fields are demagnetized and no voltage is generated. In other words, the generator does not build up its voltage.

Now, when the fields are separately excited, the machine will generate regardless of the polarity of the pole pieces and the polarity of the brushes will depend upon the direction of current in the field. This condition is shown in diagram *C*. If the field is separately excited in the same direction shown in diagram *B*, the generator will build up its voltage when self-excited again. However, if the shunt field is separately excited in the oposite direction to that shown in diagram *B*, the generator will not build up its voltage when self-excited again.

There are two ways by which the machine can be made to pick up its voltage. One method is shown in diagram *D*. In this case the shunt field leads are interchanged, which gives the original polarity but changes the brush and busbar polarity. If it is required to retain the same busbar polarity, the armature leads can be interchanged as shown in diagram *E*, which would give the same conditions as the original set-up.
Wilkinsburg, Pa. A. C. ROE.

* * * *

In answer to the question asked by W. E. H., I would say that in order to obtain residual magnetism in the field poles in case there is none, excite the shunt field from an outside source of power leaving the current on long enough so that the field poles will attract soft iron held adjacent to the poles. If the current from the armature is flowing through the shunt field in the right direction to strengthen the residual magnetism in the field this, in turn, will result in a greater voltage being generated which will cause a greater field current. This process goes on until the machine is generating its rated voltage. On the other hand, if the shunt-field current is in such a direction as to set up a magnetomotive force bucking the residual magnetism of the fields, the field is weakened to



These diagrams show in detail the cause of the trouble experienced by W. E. H. with his 55-volt generator.

such an extent that the machine will not build up.

If the machine will not build up or excite, due to the cause mentioned above, namely wrong direction of shunt-field current, there are three ways of getting it to build up. The first way is to reverse the shunt-field leads to the armature. A second method is to reverse the direction of rotation. The third way is to reverse the direction of the separate source of exciting current through the shunt field. The way to accomplish the first is apparent. As to the second, if the direction of rotation cannot be reversed it need not be considered. By the third method, a residual magnetism may be built up in the field core with the same polarity as that produced by the armature current, after the direction of rotation has been reversed.

Note that reversing the shunt field leads to the armature reverses the direction of the current through the shunt field. This enables the current to strengthen instead of weaken the field. The strong field in turn causes the machine to build up, as has been explained.

Concord, Mass. DONALD FERGUSON.

* * * *

W. E. H. asks about the cause of some trouble he is having with a small generator building up after the direction of rotation was reversed. When the machine was turned around and the direction of rotation reversed, he should have either crossed or interchanged his armature leads or his field leads in order to get it to generate. After he has done this the generator may have the oposite polarity, due to the fact that he has separately excited the fields from an outside source. If this is true and it is necessary to reverse the polarity all that he need do is to excite the fields from the busbars again, connecting the field leads to the oposite busbars.

Peoria, Ill. GEO. RINGNESS.

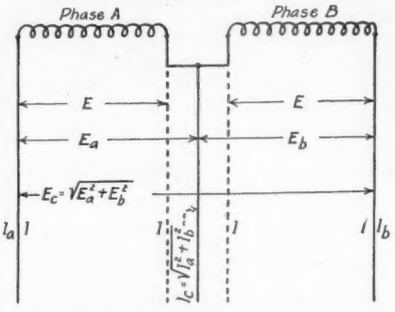
* * * *

Method of Changing Two-Phase, Four-Wire System to Two-Phase Three-Wire System.—Our power supply is from a two-phase, four-wire system. For various reasons I wish to change the distribution to a two-phase, three-wire system. Will some reader tell me how to determine which wires of the four-wire system should be connected together to form the common or neutral wire? Is it possible to tie together the wrong pair of wires to form the neutral? How should the four-wire, two-phase motors be connected to the three-wire system? Are there any precautions to take in connecting motors to the three-wire system? Will this change affect anything else in the plant?

New York, N. Y. J. M.

Answering J. M. I would say that there are several factors that should be taken into consideration in changing from a two-phase, four-wire system to a two-phase, three-wire system. In determining the proper wires to connect together for the neutral wire, many machines are designed with the phase wires of phase A and phase B in rotation on the terminal block; that is, phase A leads will be numbered 1 and 2 and the wires of phase B will be numbered 3 and 4. Since it is desired to connect the two phases in series, it will be necessary to connect wires 2 and 3 together, the center wire for the system being taken from this series tie. It is entirely possible to connect the wrong wires because connecting 1 and 2 or 3 and 4 together would cause one phase of the machine to be short-circuited.

The current and voltage relations in a two-phase, four-wire system may be determined by treating each circuit separately, as if they were two individual, single-phase circuits. However, when the system is transformed from a two-phase, four-wire circuit to a two-phase, three-wire circuit, the treatment



Comparative current and voltage relations in four-wire and three-wire, two-phase systems.

becomes more complicated. When the system has been changed from a two-phase, four-wire to a two-phase, three-wire, the phase voltages are added vectorially to find the voltage across the outside wires. This is found to be equal to the square root of the sum of the squares of the phase voltages, as, E_c (voltage across outside wires) $=\sqrt{(E_a^2+E_b^2)}$ as is shown in the accompanying diagram. A similar relation holds true for the current in the common wire. Let I=the current in each phase for the four-wire system, as shown in the accompanying diagram, and I_a and I_b equal the current in the A and B phases respectively for the three-wire system. Then $I=I_a=I_b$. Also, $I_c=\sqrt{(I_a^2+I_b^2)}$, equals the current in the common wire as is shown in the diagram. PHIL D. COMER.

San Bernardino, Calif.

* * * *

I assume that the power supply in J. M.'s plant is 220 volts and that he is going to make the change from two-phase, four-wire to two-phase, three-wire on the main distribution board. It is then a question of determining which two of the four terminals on the board can be connected together to form the neutral. The voltage should be measured across any two of the four buses or terminals. He should locate a pair of terminals that show no voltage across them. These can be connected together to form the common wire. After making this connection the voltage across the remaining pair of terminals should be 310 as read from the voltmeter. These two terminals will connect to the two outside wires of the three-wire system. If J. M. applies this test he will have no difficulty in connecting the correct pair of wires together.

In a two-phase system, one phase is 90 deg. ahead or behind the other phase. This means that at a certain instant of time, one phase generates maximum voltage while the other phase generates zero voltage. Now with one terminal of each phase connected together and measuring the voltage across the remaining terminals of each phase, the two phases will be connected in series across the voltmeter. The voltage across the two phases in series, 90 deg. apart in time phase, will be equal to the square root of the sum of the squares of the phase voltages or $\sqrt{(220^2+220^2)}=310$ volts.

The leads of two-phase motors are generally marked T-1 and T-3 for one phase and T-2 and T-4 for the leads of the other phase. So, by connecting T-3 and T-2 together to form the common wire and connecting T-1 and T-4 to the outside legs of the three-wire system, J. M. will solve the problem of connecting the motors. If the rotation of the motors has to be changed, reverse the leads of only one phase at the motor.

When changing over from a four-wire to a three-wire system, J. M. will have to consider the voltage to ground on a three-wire system. The voltage to ground is equal to 1.41 times the phase voltage. Accordingly, the insulation of the motors and equipment will be subjected to about 310 volts to ground, and there will be a greater liability of motor breakdowns, due to insulation failure on a three-wire system.

Chicago, Ill. A. NOEPPEL.

* * * *

Answering J. M.'s question, the only precaution to be observed in connecting the two wires forming the neutral, is to determine by test which pair of wires constitute a phase. When this has been done, either wire of one phase may be connected to either wire of the other phase to form the common lead. Two-phase systems are as a rule operated from generators having two separate and distinct windings. A test made with lamps, or preferably with a voltmeter will, show without question which pair of wires belong to each phase. With the usual system of four wires no reading on low-voltage circuits will be obtained if one wire of each separate phase is picked out. However, with an interconnected system, the voltage between phases will be the voltage per phase multiplied by 1.414; that is, if the voltage per phase is 110 the voltage between phases will be $110\times1.414=156$ volts. This test is, of course, one that can also be made when the common lead has been made up by testing between the outside wires. The only serious mistake that might be made is to connect together the two wires of the same phase, causing a short-circuit.

C. OTTO VON DANNENBERG.
Designing Engineer,
Sanderson & Porter,
Springdale, Pa.

* * * *

Replying to the question by J. M. in reference to changing from four-wire, two-phase to three-wire, two-phase, the first essential is to make sure by voltmeter or lamp tests between phases and from all four wires to ground that he has two non-interconnected phases.

Having found say, that the middle point of each phase is grounded or that the phases are interconnected in the generator, the connection of any two of the four wires would give a short until these interconnections were cleared.

Having determined that he has two independent phases he will find with a lamp or voltmeter that he has full line voltage from No. 1 wire to one of the other three, and the same voltage between the remaining two. Each of the other four possible ways of pairing the wires should give little or no voltage. He should connect together any two of these four potential wires, and use this jumped connection for one of his three wires, the other two wires forming the remainder of the system. Either of the other two connections would give a short-circuit.

There is, of course, every reason for connecting together the inside terminals of his four-pole service switch, interchanging wires to make this posible if need be. The same two wires (or single wire if he runs but three) should run to the inside poles or pole of every branch switch, cutout, and the like, if he expects to continue the use of any two-phase, three-wire motors.

In connecting the motors for three-wire service, the same procedure should be followed, except that, instead of getting a voltage between No. 1 wire and one other, he will find a closed circuit which he can determine with a lamp and power, or by ringing with a magneto so as to get the two pairs. Do not connect together two leads on which a ring is obtained, but join together any pair of leads on which the magneto does not give a ring. The jumpered pair should connect to the middle pole of the switch. To reverse rotation, reverse the outside poles of the switch only, never the middle.

If lights are to be connected, care must be taken to connect them between the middle pole of the switch to an outside pole, for the voltage between the outside legs will be 41 per cent more than the circuit voltage. In fusing and wiring, J. M. will likewise have to consider the fact that the middle leg carries 41 per cent more current than the outside ones. E. D. CARTER.

Engineer,
The Baylis Company,
Bloomfield, N. J.

* * * *

Referring to the question asked by J. M. regarding the method of changing a four-wire, two-phase circuit to a three-wire, two-phase circuit, he will have no trouble in making this change and can connect either of the two wires of one phase to either of the two wires of the other phase, to obtain the common wire. This common wire when so connected will carry 1.41 times the current of either phase and should have at least 1.41 times the area of either of the remaining wires.

The voltage between the two outside wires of a three-wire, two-phase system will be 1.41 times the voltage of either phase. For example in a two-phase system, one phase is 90 deg. ahead or behind the other and adding vectorially the effective voltages of both phases we get a resultant voltage of 1.41 times the phase voltage.

In other words, the voltage between phases could be obtained from the maximum point (divided by 1.41 for effective values), on the curve of instantaneous values, derived by adding the algebraic sum of the two sine waves, which represents the current value at any instant in the two phases.

The ordinary motor has two phases entirely separate and there will be no trouble in connecting one wire of either phase to either wire of the other phase. Using four wires, there are four fuses all of the same size. Since the current across the common wire, when using three wires is 1.41 times as large as was formerly carried in each of the four wires, it will be necessary to use a larger fuse in place of the two fuses previously used. If all four fuses are kept in service, care should be taken to see that the fuse contacts are kept in good order, so that the current will divide equally between the two fuses for otherwise one common wire fuse will take more than its share of the load and blow, thereby putting the load on the other common wire fuse.

Seattle, Wash. W. MONTELIUS PRICE.

* * * *

The following is my method of solving the problem given in J. M.'s question in regard to changing a two-phase, four wire system to a two-phase, three-wire system. The most complete method of making this change would take into consideration the relative polarity of the two phases, that is, after the change from four-wire to three-wire had been made, the phase rotation in the three-wire system would be the same as that of the four-wire system. By this method it would be necessary to determine the polarity of each phase in both the four-wire and three-systems, so as to make them agree. The method of determining polarity can be ascertained from the very excellent article by L. P. Staubitz in the December, 1924, issue of INDUSTRIAL ENGINEER. This method outlines the method of determining polarity at the transformer terminals. J. M. could also determine the polarity at the watt-hour meters located at the source of power supply.

In case neither of these methods could be applied, J. M. should measure the voltage across different pairs of wires until he finds a pair giving zero voltage. This pair should be connected together and the voltage measured between the two remaining wires. The measured voltage should equal 1.4 times the voltage across either phase. Should he connect two wires of opposite polarity together to form the common wire it would not cause any trouble except that it would change the direction of rotation of the rotating field, and a motor connected thereto would revolve in the opposite direction. This could be readily changed, however, by interchanging leads at the motor.

I would suggest that no fuse be placed in the neutral or common wire. The current in the neutral wire is 1.4 times the current in either of the outside wires. If the neutral fuse should blow, the motor will run single phase and since the resulting voltage is 1.4 times the normal voltage between one outside wire and neutral, considerable damage to the motor might result. Moreover, if the three-wire, two-phase system is used for lighting purposes, a blown fuse in the neutral would result in certain lamps being supplied with over-voltage, and others being supplied with under-voltage, in case of load unbalance on the two phases. Assume that one phase is loaded with five 100-watt, 110-volt lamps while the other phase has only one such lamp. Since the single-phase voltage on each phase is 110 volts, the voltage between the two outside wires will be $1.4 \times 110 = 156$ volts. If under these conditions the neutral fuse should blow, each of the five lamps in one phase will receive only 26 volts, while the one lamp in the other phase will have 130 volts applied to it.

The only other change, aside from those that I have mentioned, is to give the neutral wire sufficient capacity. Inasmuch as the current in the neutral wire is 1.4 times the single-phase current, the neutral wire should have a current carrying capacity that is 1.4 times that of either of the outside wires. P. VAN HERK.

Bressoux, Liege, Belgium.

* * * *

Replying to J. M., it is not likely that the wrong pair of wires will be tied together to form the common wire, if a voltmeter is used before attempting the connection. I have successfully made several changes of this nature recently and encountered no difficulties. It should be borne in mind that since the current in the common wire is composed of two equal currents displaced in phase by an angle of 90 deg., the resultant current is equal to 1.41 times the current in either wire. Likewise, the voltage across the two outside wires is equal to 1.41 times the voltage between either wire and the common.

For example, a two-phase, four-wire, 220-volt system, carrying a load of 100 amp. on each phase, after being changed to a three-wire, two-phase system will have 220 volts between either wire and the common, but will have $1.41 \times 220 = 310$ volts between the two outside wires. The current in each outside wire will be 100 amp., but the current in the common wire will be $100 \times 1.41 = 141$ amp. In a two-phase, four-wire system that is not interconnected, the voltage between separate phases is zero. It is only necessary to join together one wire from each phase to form the common wire.

Assuming that it is desired to make the change at the transformer secondaries, the usual method is to connect together the two inside secondaries between which the voltage is zero. In connecting motors precautions should be taken so that the two line wires that have 310 volts across them, are not connected across one phase of the motor. If care is taken to see that the common wire is connected to one wire of each phase of the motor, it is impossible to go wrong on the other two.

This change should not affect anything else in the plant that could not be corrected, so long as the common wire is always treated as one wire of either or both phases and nothing is connected across the two outside wires.

San Francisco, Calif. W. O. HURLBUT.

Electrical Service

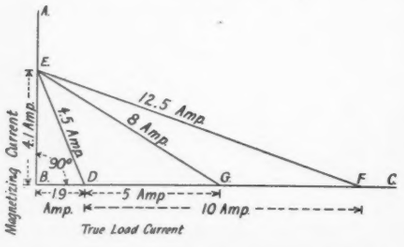
around the works

For this section short articles describing ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing, and emergency or special installations.

Graphic Method for Determining Power Output of Induction Motors

A GRAPHIC method for obtaining a fair idea of the power required to drive certain machines has been found valuable, where no wattmeter was available, or lack of time did not permit its use. This method is not claimed to be as accurate as the wattmeter method, but it certainly is more accurate than taking a current reading and multiplying by, say, 1 for 550 volts and calling the result the horsepower required. Consideration is taken of the motor losses and magnetizing currents even if they are a little high or low.

In finding the necessary data proceed as follows: (1) Note the motor rating with regard to horsepower, r.p.m., frequency, terminal voltage, and full-load current. Determine no-load current, that is, with the belt off or uncoupled, and line voltage. In the case of wound-rotor motors, the magnetizing current may be fairly closely determined simply by raising the brushes from the slip rings and measuring the primary current. (2) Take readings with an ammeter and voltmeter when the motor is driving its normal load. Make note of these readings and the corresponding line voltage. For good results, line voltage should be stable. (3) Approximate the efficiency of the motor to ascertain the losses, and also the power factor at full rated load.



The horsepower load may be determined from the current drawn by an induction motor, by means of a diagram like this, as explained in the text.

For example, take a 50-hp., 2,200-volt, 60-cycle, six-pole motor which was tested by this method and checked against its characteristic curves. Full-load current is 12.5 amp., no-load current is 4.5 amp., approximate efficiency is 85 per cent at full load, and approximate power factor is 94 per cent at full load. The losses are equal to 100—85 =15, per cent, or for this 50-hp. motor the losses would be 7.5 hp. The amperes per horsepower at full load equal 12.5÷ 50=0.25, and for 7.5 hp. this would be 7.5×0.25=1.9 amp. A full-load power factor of 94 per cent at rated voltage and frequency equals the cosine of 20 deg.

Draw any right angle as shown in the accompanying diagram. Let the horizontal line *BC* represent true power in amperes and the vertical line *AB* represent the reactive component in amperes. Then the hypothenuse will represent the line amperes as read from an ammeter. Now with any convenient scale lay off, from the intersection of the two lines *AB* and *BC* on the horizontal line, 1.9 units, or *BD*, representing the loss in amperes. From *D* draw a line *DE*, 4.5 units long cutting *AB* at *E*. *BE* represents the magnetizing current, *ED* is the no-load line current and *BD* is the motor losses at full load (all of these values are in amperes). From *E* draw a straight line, *EF*, 12.5 units long cutting *BC* at *F*. With a protractor, check angle *BFE* which should be close to 20 deg. Scale *DF* is equal to 10 units and represents 50 hp.; therefore 1 unit equals 5 hp., and we derive this constant, 5, to be used later.

We are now ready to find the horsepower required to drive the load. The ammeter reads 8 amp. and the voltage is 2,200. From *E* draw a straight line *EG* 8 units long, cutting *BC* at *G*. Since *BD* represents motor losses and *BG* represents the total input, the input minus the losses equals the output or *DG* which equals five units. Multiplying these five units by the constant 5, which was found previously, gives 25 hp., or the output required to drive the lead. If the angle *BGE* is measured with a protractor, it will be found to be 31 deg., which corresponds to cos. 0.857 or the power factor of the motor when delivering 25 hp. For a table of efficiencies and other characteristics of induction motors, consult any good handbook.

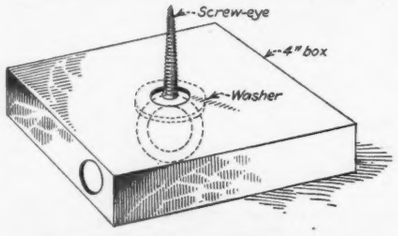
W. L. STEVENS.
New Westminster, B. C., Canada.

Method of Suspending Heavy Fixtures from Wooden Beam

RECENTLY the problem arose of suspending four heavy fixtures from a wooden beam in an inexpensive manner. There was already in place a conduit run having 4-in. square boxes fastened to the bottom of this beam where each fixture was to be located, and which was used for other purposes. This made it necessary to use these boxes or rearrange the conduit.

Accordingly a hole was drilled through each of the four conduit boxes for screw-eyes which were screwed into the wooden beams. The fixture proper was supported by three chains which were attached to a hook with a ½-in. stem, suspended from the screw eye.

The conduit box was covered by a canopy and which enclosed all of the wiring splices, as well as the screw-eye. Naturally, a job of this sort entailed the precaution of securing a good ground, which was accomplished by imbedding the screw-eye deeply in the beam so that it pressed firmly against the washer and conduit box. This job was approved by the Underwriters.



Simple suspension for heavy fixtures in a conduit installation.
The screw-eye is fastened to an overhead beam through a hole drilled in the conduit box, and grounded against the washer.

We used a screw-eye of sufficient size and strength to hold the fixture. The sketch shows how this simple suspension was made. By its use we saved ourselves the inconvenience and extra cost of changing the conduit installation.

NATHAN W. BLANCHARD.
Inwood, Long Island, N. Y.

Interlocking Control System for Overhead Tramways

THE following scheme was proposed for transporting crushed rock from a quarry to a cement mill located approximately 5½ miles distant, by using three overhead tramway systems with buckets suspended for carrying the crushed rock. The material is carried uphill out of the quarry by tramway No. 1, shown in the diagram, and then down grade to where it connects with tramway No. 2. Tramway No. 2 takes the material and conveys it to No. 3, which delivers it to the cement mill.

Buckets are suspended at equal intervals from the overhead cables of each of the three tramways, so that when a full bucket from No. 1 arrives at the dumping place, an empty bucket from No. 2 is ready to receive it. Similarly No. 2 tramway disposes of

its load to No. 3. As a matter of fact, a small amount of storage space is available between the tramways, but only enough to take care of one bucket load. It was, therefore, essential that the speeds of the three tramways be kept the same, although it was not desired to use a complicated control.

To accomplish the desired results, it was proposed to drive each of the three tramways by a 100-hp., 900-r.p.m., 440-volt, three-phase, 60-cycle, slip-ring motor equipped with a solenoid brake. When the tramways are at rest something in excess of full-load torque is required to start them moving, but when all the descending buckets are full, the motors of No. 2 and No. 3 tramways are overhauled and act as induction generators, developing approximately 80 hp. and 90 hp. respectively, and pumping current back into the line.

Tramway No. 1 differs from the other two in that the full buckets descending the 6 per cent grade are more than counterbalanced by the full buckets coming up the 16 per cent grade and it is necessary for the motor to supply the extra power necessary to operate this tramway. As this motor is always pulling a load it can never run as fast as 900 r.p.m.; its speed will always be less than this value. On the other hand, the other two motors, being overhauled, will always run above 900 r.p.m.

It is a well-known fact that the speed of a slip-ring induction motor can be changed within certain limits, by varying the amount of secondary resistance. It is probably not so generally known that inserting secondary resistance tends to increase the speed of the machine when it is acting as an induction generator, although it will decrease the speed when operating as an induction motor.

If all three tramways were geared to their respective motors with the same gear reduction it would never be possible to fulfill the requirement of operating them all at the same speed. No. 1 tramway would always operate slower than No. 2 and No. 3. It was necessary, therefore, to gear up the speed of No. 1 tramway slightly above the regenerative speeds of No. 2 and No. 3 and get speed adjustment by inserting resistance in the secondary of No. 1 motor. Besides the permanent resistors for final speed adjustments, the control equipment included three standard, General Electric, Type CR-7012-B1 starters and accelerating resistors with standard push button stations.

Important requirements of operation were: (1) Under usual conditions of operation all three tramways must operate at the same time when conveying material. (2) Stopping of any tramway must always cause No. 1 tramway to stop; otherwise there would be a piling up of material at the stalled tramway. (3) In case of an emergency it must be possible to stop the entire system from any one of four locations; that is, at each motor installation and at the cement mill. (4) If desired, any tramway must be capable of being operated independently of the others for the purpose of testing out motor and control equipment.

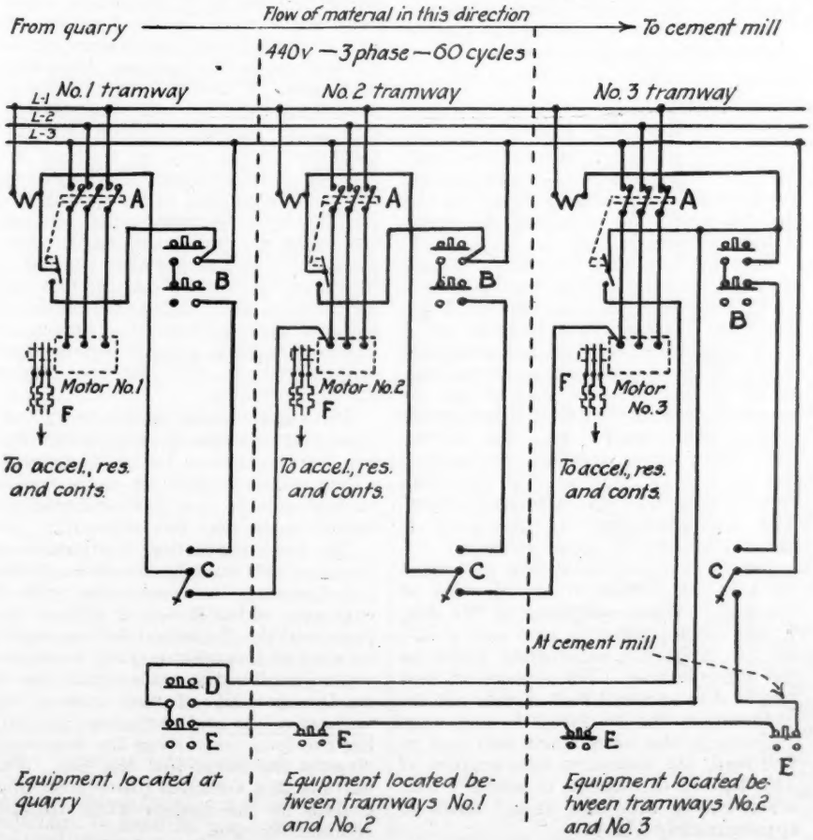
As indicated in the diagram, tramway No. 3 is started by the proper push button station located at the quarry. As soon as the line contactor of No. 3 motor closes, No. 2 motor starts up. Similarly, No. 1 motor starts when No. 2 motor contactor closes. Therefore, No. 1 motor will always shut down no matter which motor stops, which will prevent piling up of material between any two conveyors. In case it is desired to operate any starter without its being in sequence with the other two, this can be accomplished by pushing the proper double-throw snap switch *C* to the "up" position.

The above system of overhead conveying makes it possible to carry material over forest land, swamps, ridges, ravines, and so on. Also, since the material is mainly carried down grade, it is possible to obtain braking by the regenerative action of the motors, the economy of which is two-fold: (1) The regenerative current from the motors is used to run motors in the cement mill and quarry, thus reducing the load on the power plant. (2) Regenerative action is superior to mechanical braking as there is an entire absence of mechanical friction and consequently there are no brake shoes to replace or periodically adjust. The solenoid brakes referred to previously are used only as holding brakes when the tramways are at rest, or for deceleration in emergencies when the motors are shut down because of overload or voltage failure.

R. F. EMERSON.
Industrial Engineering Dept.,
General Electric Co.,
Schenectady, N. Y.

Control apparatus used to operate overhead tramway system for transporting crushed rock from a quarry 5½ miles distant from the cement mill.

A, line contactors for motors Nos. 1, 2 and 3. *B*, "Start-Stop" push button stations for individual operation of the motor starters. *C*, selective snap switches to operate motors in sequence or individually; "down" for sequence operation and "up" for individual operation. *D*, start button used for sequence operation when selective switches *C* are in the "down" position. *E*, emergency stop buttons. *F*, permanent resistance to adjust speed.



Difference Between 40-Deg. and 50-Deg. D. C. Motors and Their Ratings

UNTIL a few years ago, all direct-current motors were known as 40-deg. designs. The difference between 40-deg. and 50-deg. motors is in the temperature rise in the windings when operating at full load. Under these conditions 40-deg. motors have a maximum allowable rise of 40 deg. C (72 deg. F) above room temperature. When operating continuously at full load, they are good for a 25 per cent overload for a period of 2 hr. with a 55-deg. rise in temperature. A 50-deg. motor has an allowable rise in temperature of 50 deg. C when operating continuously at full load and has no allowance for any overload whatsoever. This means that on the basis of an average room temperature of 72 deg. F. a 40-deg. motor will rise to a temperature of 144 deg. F and a 50-deg. motor will rise to a temperature of 162 deg. F. The maximum temper-

ature is, of course, on the inside of the winding and is usually about 15 deg. hotter than the observed temperature indicated by a thermometer on the outside of the winding. The difference between this maximum temperature and the temperature of the air around the motor gives the rise.

Naturally, a 40-deg. motor will be larger than a 50-deg. motor of the same rating. The 40-deg. motor contains more laminated iron in its core and more copper in its coils because its temperature rise must be less on the same load. There is practically no difference between a 10-hp., 50-deg. motor and a 7½-hp., 40-deg. motor. The advantage in using a 50-deg. motor is nothing more or less than its first cost, whereas the 40-deg. motor will carry heavier loads and stand more abuse. It has been proven that some motors are built with too much iron for the amount of copper used. In this case the coils will rise to a temperature much higher than the iron and in the event that there is not enough iron, the iron will heat to a higher temperature than the copper.

It is very important to remember that the temperature rise of a motor is given in degrees Centigrade. The latest standardization rules of the American Institute of Electrical Engineers provide that in motors with the class of insulation used in reliable makes of motors, the temperature as recorded by a thermometer should be within a limit of 80 deg. C. This is equivalent to 176 deg. F. No one would dare place his hand in contact with the frame at a temperature anywhere near that limit.

Temperatures of motors are affected by weather conditions. Say, for instance, that a motor has a temperature of 40 deg. F. when operating continuously. Such a motor operating on a day when the normal air temperature is 70 deg. F. would reach a temperature of 110 deg. F. which would be only comfortably warm to the hand. The same motor under the same conditions on a mid-summer day when the thermometer runs from 90 deg. to 95 deg. F. will attain a temperature of 130 deg. F. to 140 deg. F. Any temerature over 120 deg. F. is uncomfortable to the hand and usually gives rise to alarm on the part of some motor users. However, a motor with a surface temperature of 140 deg. F. is in no danger of overheating. Unless there is an odor of burning insulation the motor cannot be considered in danger. According to standards of the A. I. E. E. the life of the machine insulation depends upon the actual temperature attained by the different parts, rather than on the rise of temperature in those parts. These temperatures can be obtained by using one of the standard methods.

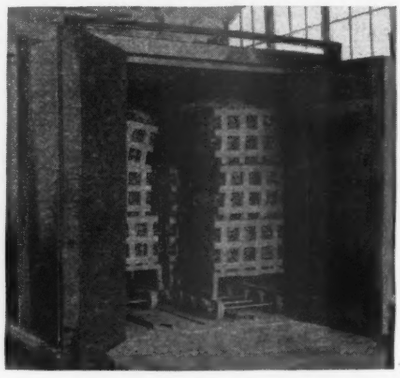
It is a well-known and proven fact that the rating of motors is determined by the continuity of operation, which must accordingly be considered in making a selection. The heating of the machine, due to passing of electric current through it, largely determines the rating.

A motor can be rated higher for intermittent service than for continuous service; conversely, a motor rated for intermittent service must not be used at the same rating for continuous service. In any service a motor can nearly always deliver more than its standard continuous rated output for short periods only, with intervening periods of rest. This fact is often overlooked and motors larger than necessary are accordingly selected.

J. K. WITHERSPOON.
Electrical Engineer,
Railway Steel Spring Co.,
Latrobe, Pa.

Electrically Heated Oven Used for Tempering Springs

AN ELECTRIC oven is being used by the Royal Blue Spring Co., of Cincinnati, Ohio, very successfully in the tempering of bed springs. Tempering is a very important process in the manufacture of these springs; for good results temperature control must be close and heat distribution uniform.



This electrically-heated oven can handle a charge of 1,800 lb. of bed springs, which are packed in steel baskets for tempering.

The spiral springs are rolled into shape by machines which were especially designed for this purpose, and packed in steel baskets. These baskets are loaded on trucks and placed in the electric oven to be tempered, as shown in the illustration.

This oven, which was built in the plant of the Royal Blue Spring Co., is 10 ft. long by 6 ft. wide by 6 ft. high. Type C, Westinghouse heaters, of a total capacity of 60 kw. are arranged along the oven sides. One of the features of this oven is that it can be loaded to capacity without injuring the quality of the work. This was not the case when other methods of heating the oven were employed, as the oven temperature was not always uniform. The maximum load of this oven is about 1,800 lb. of spiral springs.

Losses from radiation are prevented by 4 in. of insulation on all sides of the oven. When operating at 275 deg. F. the oven exterior is cold and at 475 deg. F. it is only moderately warm on the outer surface. The amount of heat radiated is so small that it does not inconvenience the workmen in any way.

Starting the oven when cold and at full load, the operating temperature of 475 deg. F. is reached in about 2 hr.; when empty this time is cut down to approximately 1¼ hr.

Regulating Equipment Prevents Load From Exceeding Maximum Demand

A NEW and interesting installation of load regulating and transfer equipment was recently made by Rockwood & Company, cocoa and chocolate manufacturers in Brooklyn, N. Y. This company purchases most of its power in the form of alternating current from the Brooklyn Edison Company on a maximum demand basis, and the object of installing the new equipment is to maintain the load on the power lines as near to the agreed maximum demand as possible.

A large proportion of the plant load is alternating current, but there is also a large number of direct-current motors and other apparatus. Power for the a.c. load is supplied directly from the incoming power lines through transformers, but power for the d.c. load is supplied by two generators, operated in parallel, on the premises. One, a 200-kw. generator, is driven by a Corliss engine which also drives a mechanical load, and the other, a 300-kw. machine, is driven by an alternating-current motor.

As the a.c. load shifts rapidly, it was previously quite difficult to hold the maximum demand within the necessary limits. With the present regulating equipment, the proper load demand on the incoming a.c. lines is maintained by automatically transferring the excess load to the 200-kw. engine-driven generator or *vice versa*.

When the two d.c. machines are first started and the load begins to come on, the current divides between them in proportion to their respective capacities. As soon as the load on the 200-kw., engine-driven generator reaches approximately 25 kw. any load above that point is diverted to the 300-kw. motor-generator set until the maximum alternating-current demand has been reached.

With this generator fully loaded, any additional load is diverted back to the 200-kw. machine until both are operating at maximum load, when a gong rings, indicating that part of the load must be taken off. If the maximum a.c. demand point is reached before the 300-kw. generator is fully loaded, the excess d.c. load will be automatically transferred to the 200-kw. engine-driven generator.

The engine which drives the 200-kw. generator is running at all times, driving its mechanical load, its generator either running light or carrying that portion of the d.c. load necessary to maintain the load balance.

The load regulating equipment was designed and built by the General Electric Company in co-operation with the engineers of the Brooklyn Edison Company and the Rockwood & Company. It consists of a contact-making wattmeter, which is directly responsible for the master control of the system, and various relays and contactors for shifting the load, protecting the equipment, ringing the gong, and the like. Push buttons and switches provide for hand control of the system when necessity demands its use.

Mechanical maintenance of

Power Drives

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through the auxiliary transmitting equipment to all driven machines.

Comment on Operating Speed of Roller Chains

ON PAGE 87 in the "Question and Answer Department" of the February, 1926, issue of INDUSTRIAL ENGINEER, A. B. Wray, Morse Chain Co., Ithaca, N. Y., expresses his opinion that 1,800 r.p.m. is too great a speed for the use of a roller chain.

Without desiring to enter into any controversy concerning the respective merits of the silent and roller types of chain, each of which has its field of application, it is unquestionably true that these fields overlap, and that the transmission of power at speeds of 1,800 r.p.m. is within the capacity of both types.

Our roller chains are recognized as being suitable for speeds, not only of 1,800 r.p.m. but considerably higher, as both single and multiple strand chains, have been used in such service for years, and new applications are being made regularly.

W. A. WARRICK.

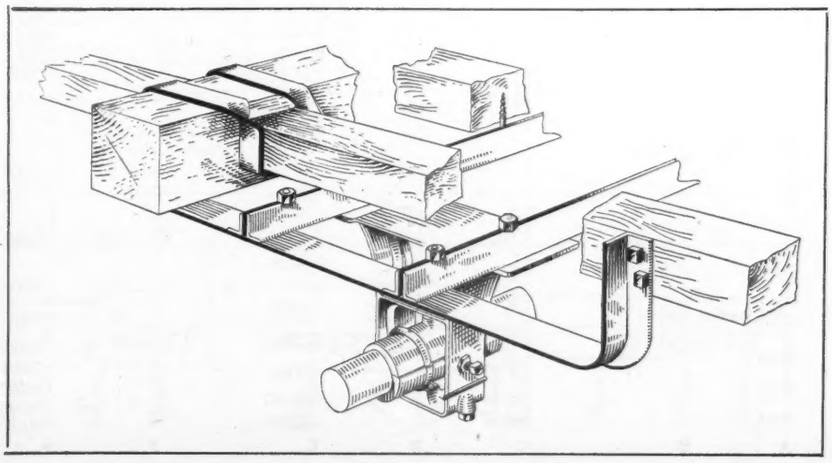
Mechanical Engineer,
Diamond Chain & Mfg. Co.,
Indianapolis, Ind.

Supporting Lineshafts in Mill-Type Building on Standard Angle-Iron Groundwork

WHERE the buildings of an industrial plant are of a uniform type many economies result from the establishment of a standard form of construction and installation of lineshafts. Two of the main advantages are that the men know exactly how the work is to be done and so can go ahead with less supervision; also when it is necessary to make a change in the location of a shaft practically all the material is re-usable without additional fabrication.

The standardized groundwork used by the Master Mechanic in one large industrial plant is shown in the accompanying sketch. As may be seen from the drawing, this consists practically altogether of standard angle irons which are laid in pairs to take the feet of the hangers. These footings are supported on other angles which are bent so that they may be fastened to the beam construction by lagscrews. To give the rails or footings additional support a few long lagscrews extend from between the rails to the ceiling beams, as shown. These extra lagscrews are placed near a hanger and on the opposite side from the angle-iron cross-piece supporting the rails.

This Master Mechanic, also, has the feet of the hangers planed to give them a more firm and true footing against the angle-iron rails.



This form of standardized construction of groundwork for supporting lineshafting in mill-type buildings is used in one large industrial plant.

Operating Economies Which Resulted from Installing Ball-Bearing Lineshafts

IN 1913 our manufacturing load had become so great that our power plant was inadequate to handle it. Something had to be done and we decided to cut down the amount of power that was being wasted in overcoming lineshaft bearing friction. Ball-bearing hangers and pillow blocks were first installed on the lines where the friction load was considered to be greatest; namely, shafts carrying heavy loads with the belts all pulling in one direction. Other shafts were equipped later. These hangers were of the SKF type, which are now used almost exclusively in our plant.

The shafts driving the punch presses, grinders, emery wheels, and grindstones also run in SKF hangers and pillow blocks. Similar bearings are used in the fans and blowers and in the emery wheel stands. The sizes of the shafts vary from 4 in. down to $1\frac{7}{16}$ in. in diameter and the operating speeds vary from 12,000 r.p.m. for the emery wheels to 200 r.p.m. for the lineshafts.

A large saving in power has been attributed to the decrease in friction losses which have been obtained through the use of these bearings. One section of the plant which is supplied by our direct-current generator required between 1,600 and 1,800 amp. at 130 volts before the new bearings were installed. With the same load the current is now 1,200 to 1,300 amp. This has given a minimum reduction of 400 amp. or 25 per cent of the original load. The average power saved per day is 468 kw.-hr., which in a year's time, at $0.02 per kw.-hr., is worth $2,808. As this section of the plant takes about one-third of the total amount of power used, the saving from the use of ball bearings in the entire plant would be approximately $8,424 per year. The power economy alone at this rate would pay for the complete installation in less than two years.

The old plain bearings often burned out in the grinding room and other places where the service was especially severe, but the new bearings have given us practically no trouble and have stood up excellently on the hardest jobs. Our polishing machines provide a good test of a bearing. The old bearings lasted about three or four months, but the new bearings installed in these machines have been in use for several years. Formerly the bearings of one of our fans had to be rebabbitted at least every six months. The new bearings have operated three years and have not caused any trouble, even though the fan operates in a dirty location.

The oiler greases each bearing every 90 days although once in six months would probably be sufficient. Once a year the bearings are cleaned and repacked with grease. The old plain bearings were oiled every day. The cost of lubricating oil used was considerably more than the present cost of the grease.

W. A. ATKINS.

General Superintendent,
A. C. Atkins & Co.,
Indianapolis, Ind.

Using Chart to Determine Horsepower Loss from Friction in a Bearing

THE principal function of the accompanying chart is to speed up computations on bearings and their friction losses. The ease with which these computations can be made with this chart should increase the use of actual figures in bearing design and operation, instead of the rough estimates or guesses, that are frequently employed.

To use this chart, it is necessary to lay a straight-edge across it three times, as indicated by the dotted lines. It will give the horsepower consumed by any bearing with co-efficients of friction varying from 0.0006 to 0.6, with shaft diameters from 0.1 to 10 in., at speeds from 100 to 10,000 r.p.m., and with a load on the bearing varying from 10 to 10,000 lb.

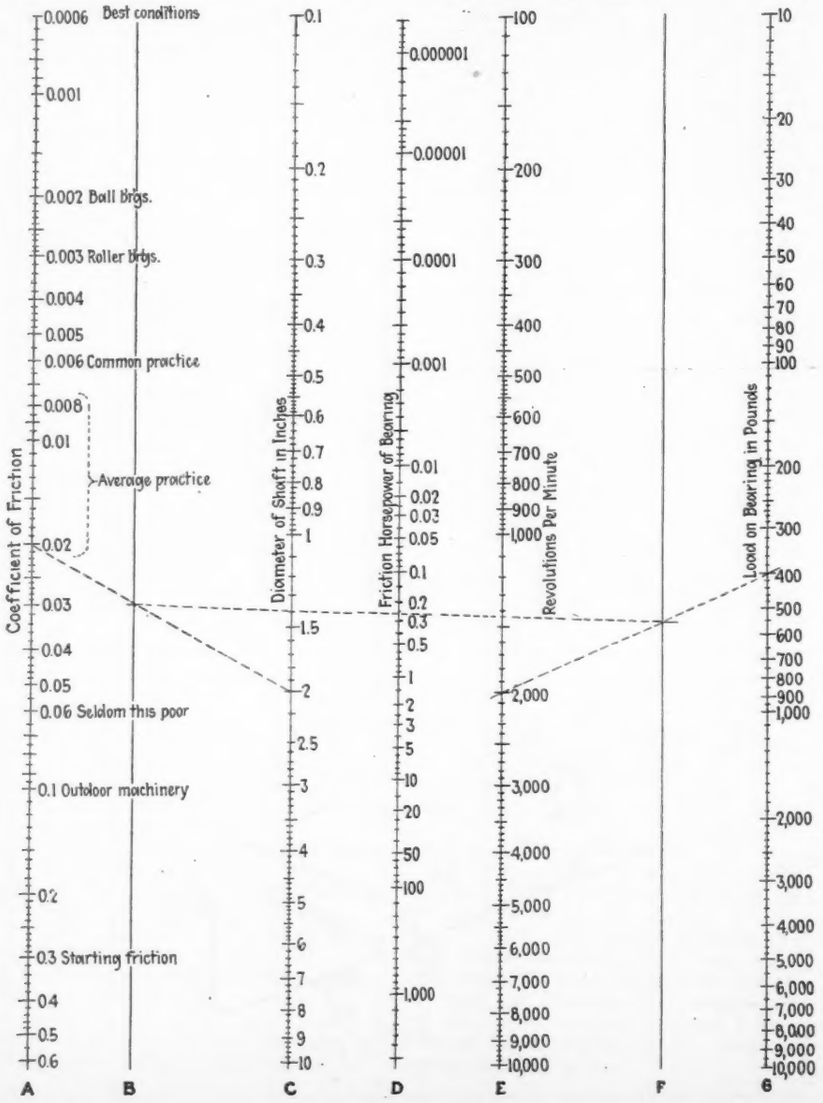
For example, assume that in a particular bearing the co-efficient of friction is 0.02 (column *A*) which is average practice for plain bearings, the shaft diameter is 2 in. (column *C*), the speed is 2,000 r.p.m. (column *E*), and a 400-lb. load is carried by the bearing (column *G*). Column *D* gives the friction loss as a little over 0.25 hp. To get this result connect with a straight-edge the known value in column *A* with that in column *C* and locate the intersection with column *B*. In the same way connect columns *E* and *G* and locate the intersection with column *F*. Then connect the intersections (columns *B* and *F*), and the intersection with column *D* will give the friction horsepower loss of the bearing.

The notations alongside column *A* indicate the co-efficients of friction met with in everyday practice, beginning with the very best conditions of plain bearings and ending with starting friction. Co-efficients of friction under the many possible conditions may be obtained from text-books, such as Alford's "Bearings" and in such handbooks as "Kent" and Mark's new "Mechanical Engineer's Handbook." Only the safe values of approved practice are designated on the chart. As will be noted, a co-efficient of 0.002 is used for ball bearings and 0.003 for roller bearings. All the other co-efficients (column *A*) relate only to the plain bearings.

The chart can, of course, be used backward as well as forward. For example, if the power absorbed by a given bearing is known and the values in columns *C*, *E* and *G* are known, the co-efficient of friction may quickly be determined. Then, knowing the co-efficient of friction with a given oil and in a given bearing, the power required by a similar bearing of different diameter, speed and loading may be found with an accuracy sufficient for most practice.

W. F. SCHAPHORST.
Mechanical Engineer,
Newark, N. J.

With the factors which affect friction, known or estimated from practice, the horsepower loss in any bearing can be easily determined by using this chart.



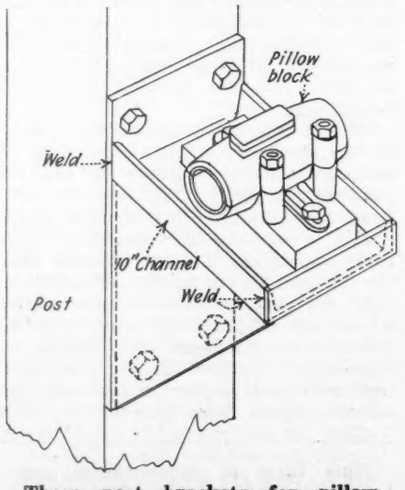
Method of Welding Up Steel Post Bracket for Pillow Block

WHEN it is necessary to support lineshafting from wood or steel columns and cast-iron brackets are not available, a very solid and effective bracket can be made out of a piece of heavy channel iron and several pieces of steel plate. A method of doing this is shown in the accompanying sketch.

The piece of channel must be wide enough to carry the size of pillow block on the inside or web of the channel and at least 2 or 3 in. longer than the block.

The bracket is made by welding two triangular pieces of ⅜-in. steel plate to the bottom of the channel and also to a piece of ⅜-in. plate of rectangular shape which is attached by bolts or lagscrews to the column, as is shown in the accompanying sketch. The front of the channel has a piece of lighter gage plate welded across it, which forms, with the sides of the channel and the back plate, a reservoir to retain any oil which leaks out of the bearing. Holes are cut in the web of the channel, so that the pillow block may be bolted down. Surplus oil is removed through a drain which consists of a short nipple with a pipe cap. The nipple can be welded on or a hole bored through the web and tapped.

Hollywood, Calif. M. C. COCKSHOTT.



These post brackets for pillow blocks were made up from a piece of channel and three steel plates welded together.

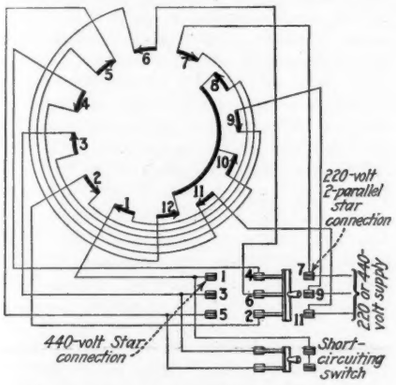
In the Repair Shop

This section is devoted to repair work on electrical and mechanical equipment. Special attention is given to shop or bench tools and short cuts or improved methods of handling work of this character. Contribution are always welcome.

How to Connect Motor for Use on 220 or 440 Volts

IN PLANTS where 220 and 440 volts are used, spare motors might have to be cut over in a hurry from one voltage to the other and a great deal of time lost by reconnecting. There is also the possibility of rented motors or portable sets having to be reconnected to suit the voltage.

The winding of a three-phase, four-pole motor can be arranged for quickly changing the connection from single star to two-parallel star or *vice versa*, by bringing out nine leads and connecting them to a three-pole, double-throw, knife-switch, as shown in the diagram.



For a four-pole motor, nine leads are brought out from the stator winding and connected as shown.

By throwing the three-pole reversing switch to the left a 440-volt, single-star connection is obtained. When leads *1*, *3* and *5* are short-circuited and the reversing switch is thrown to the right, a 220-volt, two-parallel star connection is made.

By throwing the switch to the left, a single-star connection is formed, for use on 440 volts. With the switch thrown to the right, the winding is connected two-parallel-star for 220 volts. When the switch is in this position, terminals *1*, *3* and *5* must be shorted by a double-pole, single-throw switch to form the other star point.

This method can be applied to either a four- or six-pole winding. When connected for six poles, the groups must be laid out and numbered in the same way as for four poles, only there will be 18 groups instead of 12, as in a four-pole connection. Consequently there will be more jumpers, but there will be 12 leads from 12 consecutive groups; the first six will be starting leads and the last six will be finishing leads. It makes no difference which leads you count as the same connection is obtained. Out of 12 leads, Nos. *8*, *10* and *12* form the star, and should be connected inside of the motor. This is done also in the four-pole connection in the diagram.

Los Angeles, Calif. HENRY KAELIN.

Comment on "One Man Should Be Responsible for Plant Operation"

I READ with much interest, "One Man Should Be Responsible for Plant Operation," on the editorial page of the November, 1925, issue of INDUSTRIAL ENGINEER. In my opinion, based on experience in the electrical and mechanical departments, the direct result of having one head for the two departments will accomplish one very essential condition necessary for successful maintenance: that is, "team work."

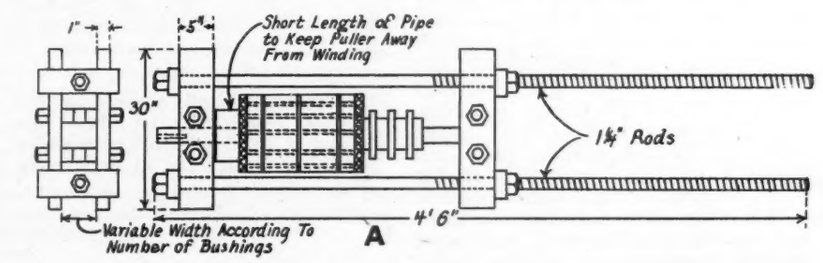
As a preliminary step, I believe the men selected as foremen of the mechanical and electrical departments should be both willing and capable of being trained in each of these branches. This will result in better and faster work as each one will know what the other fellow is up against. Then again, it puts these men in a competitive position to fill the maintenance engineer's job should that become vacant. I might add that the Master Mechanic or Maintenance Engineer is usually a mechanical-electrical man having charge of both departments.

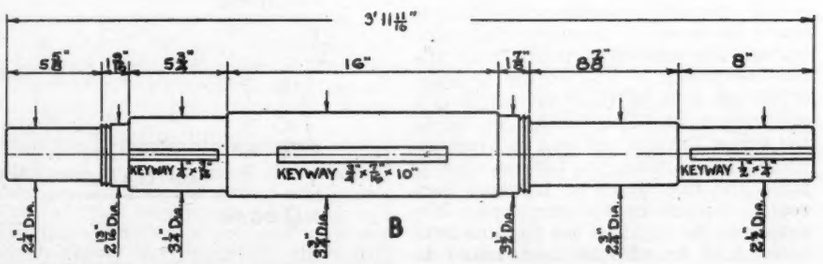
The following repair job which came in a few days ago will illustrate the result of team work at this plant. One morning recently a steamer with 4,000 tons of coal came in to be unloaded, and shortly before she docked the shaft of the 40-hp. induction motor operating the conveyor belt broke at the inside end of the bearing, allowing the rotor to drop and damage several rotor cells. This happened about 9:30 a. m.; at 11 a. m. the motor came into the shop and an emergency requisition was made out for shaft stock, which arrived at noon. Meanwhile the rotor was taken out and upon test was found to be grounded. As no press was available the puller, shown in *A* of the accompanying diagram, was rigged up. Both core and rings were very tight on the shaft and required two men with 3-ft. extensions on the wrenches to draw them off. Roughing out the shaft commenced at 12:30 p. m. By 3 o'clock the rings were off, and the core was removed at 6:30 p. m. Meanwhile the bearings had been poured and were being bored out.

The electric shop had the core at 6:45 p. m. and upon testing it found that the trouble was confined to one phase. As there were four coils per phase per pole, we disconnected the four coils at one spot on the back end and after testing again, disconnected two more further on. More tests showed the trouble to be between the

Teamwork and ingenuity were the deciding factors in speeding up this emergency motor repair.

A is a puller that was rigged up to remove the rotor shaft. *B* shows the amount of work which was necessary on the rotor shaft that was turned out in about 15 hr.





disconnected places and after removing the connectors of these coils at the front end, the trouble showed up in two slots only. The bands were removed and enough connectors were taken off to remove the defective coils. New coils which we had on hand from a previous job were inserted and tested out with a Megger.

A little rivalry developed between the two departments as to which one would be ready first. The machine shop won by 1½ hr., having finished turning the shaft at 2 a.m. and cutting the three keyways at 4:00 a. m. the following morning. The electric shop finished at 5:30 a. m., except for the connections to the star ring and banding, which had to be done after assembling. Diagram *B* shows the amount of work done on the shaft, the material of which was 3⅞ in. in diameter. Assembling was finished at 8:30 a. m. and the same rigging which was used to pull the core off the shaft aided again in the work. At 8:45 a. m. the star ring was being soldered and the connectors straightened up, after which a thorough examination for solder bits between coil ends was made. The core was banded and completed at 11:15 a. m. and at 12:30 p. m. the motor was completely assembled and left the shop. The motor had to be transported about ⅛ mile and hoisted up 45 ft. to its position on the bridge. It was in operation at 3:00 p. m. of the same day, being out of service just 29½ hr. If a press had been available for removing the rotor shaft, considerable labor would have been saved and the total time out of service reduced 1½ hr., as the electrical department could not commence work until 6:45 p. m. of the previous afternoon.

CHESTER A. WILLIAMS.
Electrical Dept.,
Providence Gas Co.,
Providence, R. I.

Making the Slide Rule Add and Subtract Percentages

ANY ordinary slide rule can in a few minutes be adapted to add and subtract certain fixed percentages, by the simple method described here. The adding and subtracting feature consists of a small arrowhead placed on the underside of the glass slider and permits the addition or subtraction of percentages up to about 25 per cent on the *A* and *B* scales, and about half that amount on the *C* and *D* scales. Placing the arrowhead as shown in the accompanying illustration does not interfere with the operation of the slide rule when using it for other work. It is essential, however, that it be made and located carefully or it will be of doubtful value.

For example, in reading the *C* and *D* scales as noted on the slide rule illustrated, the arrow to the left of the hairline points to 2.85 on the *D* scale, or 95 per cent of (1.5×2), which is a subtraction of 5 per cent. To locate the arrow for this per cent subtraction, place the hairline on 1.05 on the *D* scale and the arrow at 1, which then really represents 95 per cent. The arrow at the right of the hairline indicates 3.15 or addition and would be located by placing the hairline on 1 and placing the arrow at 1.05 on the *D* scale. By simply moving the slider glass to any value desired on the *D* scale, the fixed ratio of 5 per cent addition or subtraction may be read. The same procedure is used for locating the arrow for any other percentage or when using scales *A* and *B*.

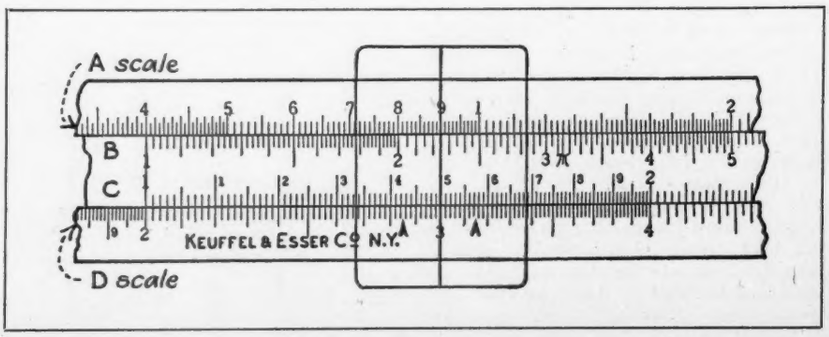
For example, to locate the arrow for 15 per cent addition on the *A* scale, the hairline would be placed on 1 and the arrow located at 1.15.

An arrow cut from a piece of black carbon paper will answer the purpose very satisfactorily. Supposing it was desired to add 10 per cent on the *C* and *D* scales. The arrow should first be moistened on the back or plain side of the carbon paper and stuck on the *D* scale, being adjusted with a pin at 1.1, so that the point just touches the smallest graduations. The glass, from which the bottom or spring runner has first been removed, should be touched with library paste at the place where the arrow will come. Next, the glass should be moved, with the top runner firmly pressed against the rule, to a position where the hairline will coincide exactly with 1, and then gently pressed down upon the arrow, which will adhere to the bottom side of the glass. It should be left to set for perhaps a minute, and then removed and allowed to dry. When dry, the superfluous paste should be carefully trimmed from around the arrow, and a small drop of white shellac applied over and around the edges of the latter. When the shellac hardens it may be carefully trimmed with a sharp knife, so as to leave a protecting coat around the edge of the carbon paper. By making the arrow in this way it will be found to last indefinitely and will stand any rubbing necessary to clean the glass. At the same time, it can be quickly removed when one desires to change the percentage reading.

A slide rule altered in this manner is very useful, for instance in estimating, where a certain fixed percentage of profit must always be added to figures obtained, or in adding overhead to cost figures. In the case of slide rules which have a sufficiently wide glass, an arrow may be placed to eliminate one operation in reading the area scale. A 15 per cent arrow will also serve to show, for instance, the width across points of hexagon stock where the width across flats is given. It will be easy to find a good many applications for this scheme, including some where a given percentage also has two or more useful meanings.

Santa Ana, Cal. HENRY SIMON.

By placing small arrows at the proper points on the slide rule glass, a fixed percentage may be added or subtracted at each reading.



Changing the Frequency of an Induction Motor

OFTENTIMES it is very desirable to change a 25-cycle motor to a frequency of 60 cycles. The latter frequency is found more desirable for ordinary purposes when overload is not encountered to any great extent. The question of how to make such a change is frequently raised, and this article will show the procedure in a particular case.

In order to change a 25-cycle, 440-volt, 750-r.p.m. squirrel cage induction motor over to 60 cycles at the same speed and voltage, it is necessary to rewind the motor. The reason for this is, that a 25-cycle motor operating at 750 r.p.m. has four poles, while a 60-cycle motor requires ten poles to give the same speed. If the coil pitch of the four-pole, 25-cycle winding is between 50 and 70 per cent and the winding is reconnected for eight consequent poles, that is, four north-pole groups, the motor will operate under the same conditions as would a 538-volt motor on a 440-volt line, or 20 per cent undervoltage. A number of coils equal to 10 per cent of the total should be cut out, which would reduce the full-load rating at least 15 per cent.

In following the above procedure, the resistance of both the end rings on the motor will have to be increased to help provide sufficient torque without pulling excessive current at starting. The end resistance may be increased as follows: where the construction and type of the rotor permit place it in a lathe and turn it down. This is a cut-and-try procedure, as anywhere from 20 to 50 per cent reduction in ring area may be required. A second method is to put saw cuts in the rings between each bar of both end rings.

For slip-ring motors or wound-rotor types, the rotor winding must be changed whenever a change is made in the number of poles in the stator winding. Additional information on changing the frequency of induction motors can be found on page 187 of the April, 1924, issue of INDUSTRIAL ENGINEER.

Wilkinsburg, Pa. A. C. ROE.

Practical Books
for your personal library

Every man who aspires to larger responsibilities should build up a professional library containing carefully selected volumes on subjects related to his work. Copies of the books which are reviewed here may be obtained from the publishers mentioned.

Electrical Engineering—By Clarence V. Christie, Consulting Engineer and Associate Professor of Electrical Engineering, McGill University, Montreal, Can. Published by McGraw-Hill Book Co., Inc., 370 Seventh Ave., New York, N. Y., third edition, 605 pages, illustrated. Price $5.

In the preparation of this third edition considerable new material was added to bring the volume up to date in addition to making a thorough revision of the second edition. This book was written for use as a textbook and considerable attention is given to the theory of the problems involved. Many of the fundamentals of design of various types of electrical equipment are discussed.

* * * *

Elements of Alternating Current and Alternating-Current Apparatus—By J. L. Beaver, Assistant Professor of Electrical Engineering, Lehigh University. Published by Longmans, Green & Co., 55 Fifth Ave., New York City, 363 pages, illustrated. Price $4.

This book has been prepared for beginners, either electrical or non-electrical students, in the study of alternating currents. The first eight chapters deal with the principles of alternating current in a very elementary way. The vector method of treatment is used as much as possible throughout the text. The last five chapters are devoted to the study of the more common types of alternating-current apparatus, beginning with the transformer. Special questions, which bring out the important details of the text, and problems (mostly with answers) are a part of each chapter.

* * * *

Industrial Electricity, Part II—By Chester L. Dawes, Assistant Professor of Electrical Engineering, The Harvard Engineering School, published by McGraw-Hill Book Co., Inc., 370 Seventh Ave., New York, N. Y., 472 pages, illustrated. Price $2.75.

This volume discusses alternating-current circuits and equipment and is thus a continuation of Part I, which was devoted almost entirely to direct-current circuits and direct-current machinery. The first chapters of this volume are devoted to the fundamental principles and the simple laws governing alternating currents and alternating-current circuits. However, only the simplest mathematics are used. Considerable emphasis is placed on the effect of inductance, capacitance, and frequency in the flow of alternating current.

A chapter is devoted to the construction and uses of the ordinary alternating-current instruments. The relations existing between current and voltage in polyphase systems are pointed out. Likewise the construction and operating characteristics of alternators, polyphase induction motors, single-phase motors, synchronous motors, and converters are explained and briefly analyzed. The relations between the characteristics of these types of power machinery and their industrial applications are also discussed to a considerable extent. The last three chapters are devoted to general industrial applications of electricity, including the methods and general rules which should be followed in the installation of wiring.

* * * *

Processes of Flour Manufacture—By P. A. Amos. Third Edition, published by Longmans, Green & Co., 55 Fifth Ave., New York, N. Y., 299 pages, illustrated. Price $3.

This volume is one of the technical handicraft series. The author in the additions to and revision of previous editions has endeavored to include all the latest and most important developments of the flour milling industry, both in machinery and manufacture. In addition to a thorough discussion of wheat and flour, together with the methods of cleaning, handling and milling, several pages are devoted to such subjects as: power and power transmission, fire risks and safeguards, mill lighting, capacities and speeds of machines, and other general data. An interesting feature of this booklet is that practically all the operations and machinery are shown by diagrams and cross-sections of the equipment.

* * * *

The Induction Motor—By Herbert Vickers, Professor of Electrical Engineering and Head of Department of Mechanical Engineering, University of British Columbia. Published by Isaac Pitman & Sons, 2 W. Forty-fifth St., New York City. 319 pages, illustrated. Price $6.

This book discusses the theory, design and practical application of the induction motor and has been prepared especially for designers, consultants and students. It goes, therefore, very deeply into the theoretical discussion of these subjects. An attempt has been made to deal with the latest developments in speed and power factor control, and to incorporate most of the theory connected with the motor and its application.

* * * *

Practical Radio—By James A. Moyer and John F. Wostrel. Published by McGraw-Hill Book Co., Inc., 370 Seventh Ave., New York City, second edition, 266 pages, illustrated. Price $1.75.

This second edition has been made necessary by the changes and remarkable development of radio equipment. Two of the important additions are the radio trouble chart and a chart which shows the important characteristics of various radio receiving sets.

Power-Factor Wastes—By Charles R. Underhill, Consulting Engineer. Published by McGraw-Hill Book Co., Inc., 370 Seventh Ave., New York City, 296 pages, illustrated. Price $3.50.

One object of this book is to acquaint those directly responsible for the large proportion of power factor wastes, and who pay the bills therefor, with how much these wastes cost, as reflected in actual savings, with a discussion of their causes and cures. The aim is to present as many sides of the question as practicable, with a thorough discussion, which reflects the opinion of a number of authorities.

The subject of power factor and its correction is discussed from the power user's standpoint, with details as to how the user can correct power factor and the advantages which will result.

The manner in which the subject is treated is shown by the chapter headings, which are as follows: Introductory; power factors, wires, and voltages; importance of keeping motors loaded; analyses of power bills; transmission, distribution, and rates; symposium of the power factor situation; fundamental principles of the power factor and its correction; some characistics of induction motors; correction of the power factors of induction motors; the plant distribution system; synchronous machinery in power-factor correction; static condensers; correction of the induction motor with static condensers; capacitors; power-factor correction with Fynn-Weichsel motors; improving the power factor with the electric furnace; location of power-factor-corrective apparatus; status of power-factor corrections; statistical data; general and summary.

* * * *

Signal Wiring—By Terrell Croft, Consulting Engineer. Published by McGraw-Hill Book Co., Inc., 370 Seventh Ave., New York City, 338 pages, illustrated. Price $3.

This book has been prepared from the standpoint of the man who is to install the signal wiring and so is written largely from the standpoint of the considerations involved in laying out the circuits; no attempt has been made to discuss the design or manufacture of the devices themselves. Because the information which is ordinarily desired relates to the connection of the apparatus and the layout of the circuits, this book contains over 460 circuit diagrams which illustrate the various points brought out.

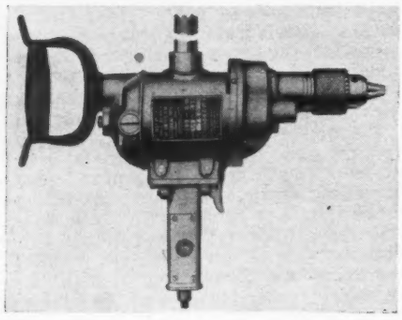
The different types of signal systems which are discussed and diagrammed are well indicated by the following chapter headings: Bells and annunciators; burglar alarms; hospital and hotel signals; time- and program-clock circuits; auto-call signaling circuits; telephone circuits; fire alarm circuits; watchman and police call circuits; power station signaling; water flow and pressure alarms; elevator signaling; mine signals; railroad signaling; miscellaneous signaling circuits; batteries, transformers and signaling devices. The sixteenth and last chapter, on "Signal Wiring Methods," gives the National Electrical Code requirements and in addition, discusses conductors and cables, their supporting and installation, lightning and excess-current protection, batteries, motor-generators and low-voltage transformers and other equipment used in installations of this character.

New Equipment
for plant operation and maintenance

Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

Portable Electric Drills

TWO ½-in. portable electric drills have been brought out by the United States Electrical Tool Co., Cincinnati, Ohio. These are a ½-in. heavy-duty model, and a ½-in. special drill, which is shown below. The former is of heavier construction to stand up under more severe requirements. The latter is for general, all-purpose work.

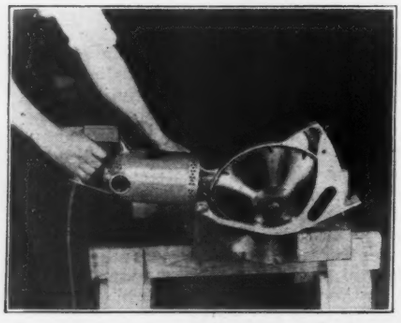


Both tools have a spade handle which can be removed by loosening either of two screws so that the drill can be secured to the adjusting screw of an "old man."

The motors are designed to operate the drills at 450 r.p.m., full-load speed. Three S K F ball bearings are used in these drills. A ball-thrust washer is placed behind the drill chuck. The motors are controlled through a trigger switch which has an "on and off" indicator; the "off" position is indicated when the arrow is crosswise to the line. Ventilation is provided for the universal motors which are designed to operate on direct or alternating current of 60 cycles or less.

Portable Motor-Driven Saw

ANNOUNCEMENT is made that the Crowe Mfg. Corp., 133 E. Third St., Cincinnati, Ohio, has placed on the market a portable motor-driven circular wood saw. This saw has a guard so arranged that it is impossible for the workman to remove the saw from the board without the guard covering it and locking itself so that it cannot be removed until it is again on the board in a position for sawing. A trigger switch is so arranged that it must be held in contact to keep the saw running. This saw is made in three sizes that will handle practically any timber used in building. Universal motors are supplied for 110- or 220-volt service, which permits connection to any socket.



Portable Vacuum Cleaner

AN entirely new design of semi-heavy-duty, portable vacuum cleaner with dust-blower attachment has been placed on the market by the Allen & Billmyre Co., Inc., Grand Central Palace, New York City. This machine is used for light dust removal work in factories of various kinds and the dust-blowing attachment should make it a valuable acquisition for any plant using electrical apparatus.

This machine, as shown in the accompanying illustration, is equipped

with a ½-hp. Universal Westinghouse motor; it weighs 105 lb., and is very compact and ruggedly built. A machine for this type of work can be classified as coming between the small household vacuum cleaner and the heavy-duty portable and stationary cleaners.

Machine for Winding Springs

COIL springs for replacement may be made by the Rapid Spring Winder, which is a portable device to be clamped on a bench and operated by a crank. This device is announced by the Fostoria Screw Co., Fostoria, Ohio. It is possible, according to the manufacturer, for any one to make coil springs in any ordinary size, any length, and in either right- or left-hand lead or twist as desired.

The size of the spring is determined by the size of the mandrel used, while the pitch or lead of the spring is determined by the position of the little cam. This can be set in any position to produce a spring of any desired pitch.

Lever-Operated Master Switch

LEVER-OPERATED master switches for steel mill service or other work where strength and durability are important factors are announced by the General Electric Co., Schenectady, N. Y. The new switch is particularly suitable for grouping and for operation by one man. It has been assigned the designation C-3003 in the CR-3012 series of control equipment. The C-3003 master switch is flat and semi-circular in general shape and consists of a cast-iron frame and cover which totally enclose the contact mechanism. This design permits convenient grouping within easy reach of one operator.

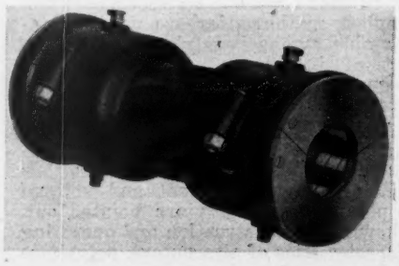
The handle is of the vertical type, operating through a radius of 40 deg. on a one-point switch and through a 100-deg. total radius on the three-point switch. Operation from one position to another is very free, it is said, as there are no gears or other friction surfaces other than the bearings and contact fingers. The handle is held in the "off" position by a spring roller device. This switch is made in several forms, the C3003-B shown above being standard.

Narrow-Center Hanger Bearing

LINESHAFT roller hanger bearings with a narrow center, which are designed for an exact size-for-size replacement box, have been announced by the Hyatt Roller Bearing Co., Newark, N. J. This bearing box is completely split for easy installation and fits any type of hanger. The distinctive, helically-wound rollers are retained. The box is of dumb-bell shape, as shown in the accompanying illustration, with twin split-roller assemblies mounted at each end. The center section, which is free from bearing surface, is narrowed down to average plain-bearing dimensions to fit hangers with narrow frame openings.

The box is built in two sections, the lower part forming two-thirds, and the top, one-third. This brings the machined joint well above the oil level and prevents oil leakage. Tightening four bolts, seals the sections around a shaft. Bosses are staggered so that the top cannot be improperly fitted. A small wrench is the only installation tool used.

The Hyatt Co. reports that one filling of lubricant every three or four months is the only attention this new bearing

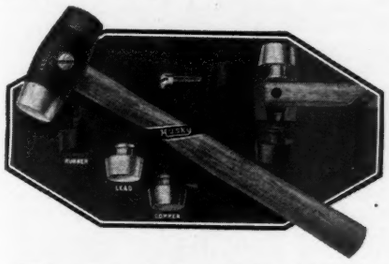


requires. Grit and other substances that tend to break down the oil film are drawn away from the bearing surface through the slots in the hollow rollers.

Manufacture at present is confined to five sizes, $1\frac{7}{16}$ in., $1\frac{11}{16}$ in., $2\frac{3}{16}$ in., $2\frac{7}{16}$ in., and $2\frac{11}{16}$ in., for which the demand has been greatest. For use with larger sizes of hangers requiring bearings up to $4\frac{11}{16}$ in., the old line of U. G. and B. & S. type Hyatt bearings are being continued.

Interchangeable Soft-Tip Hammer

PATENT and manufacturing rights to the interchangeable soft-tip hammer illustrated have been acquired by the Husky Wrench Co., 928 Sixteenth Ave., Milwaukee, Wis. The hammer is made in 2- and 4-lb. sizes.



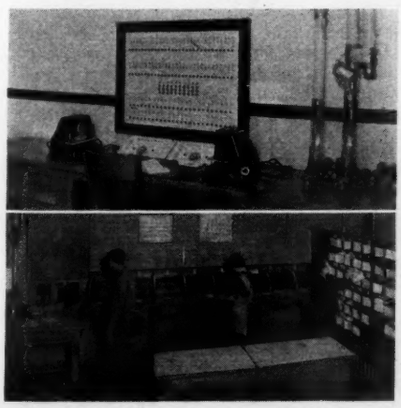
Hammers are supplied with interchangeable soft tips of copper, lead, rubber or other material as desired. They are marketed in sets with two of each kind of tip. The tips can be replaced after loosening the filister-head screw and separating the housings.

Maintenance and Production Control System

ANNOUNCEMENT is made by The Temporator Co., 548 Orleans St., Chicago, Ill., of the development of an electric signaling system for the control of production and operation, including maintenance, in industrial plants. This system consists of a central switchboard, one or more so-called service stations, and a number of dialing stations, similar to the dial on an automatic telephone, installed at the machines and in other locations in the plant. The central switchboard and a service station are shown in the illustration below.

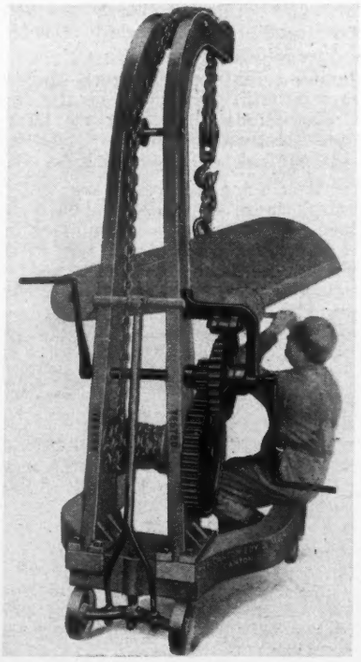
The operation of the system is as follows: Through a scheme of code numbers the machine operator dials all desired information, such as the time of starting a job, notification that stock or raw material is getting low, requests for oiling, adjustment or other maintenance service, and so on. The code numbers conveying this information are shown through a number of little windows in the switchboard.

The switchboard operator records all incoming calls so as to determine time, cost, and production schedules, and also records and dispatches to the proper station all calls for maintenance service. The operator does this by flashing, from a dial on the switchboard, the number of the maintenance man and the code number of the service required on a conveniently-located, overhead visual placed in the plant department concerned. A bell also rings to attract the attention of the maintenance man. In answering the call he goes to his service station, jots down the number of the machine that requires attention and gives this machine the desired service.



Portable Crane With Load Brake

HERETOFORE, most cranes have been built with a ratchet and pawl, but the Canton Foundry & Machine Co., Canton, Ohio, has just developed and has ready for the market, a new improved Canton portable crane, with a safety friction load brake, which is shown in the accompanying illustration. It is stated that with this load brake on a crane, the load is held at any point; it can not under any condition get away from the operator; that this brake insures positive safety to the operator and to the work handled; and that it complies with safety regulations throughout the country.



This friction load brake operates by means of friction disks in connection with a helix and is so designed that the pawl is always engaged in the ratchet; it is necessary to wind the load down as well as to raise it. In this way, according to the manufacturer, the load cannot get away from the operator, whether or not he lets loose of the handle. This unit is built not only for new portable cranes, but is so designed that it can be installed in Canton cranes now in service.

Vertical Electric Car Spotter

A NEW, vertical-capstan, electric car spotter, known as the Caldwell Car Spotter, has been announced by H. W. Caldwell & Son Co., 1700 S. Western Ave., Chicago, Ill. Twenty pounds pull on the capstan, it is asserted, will serve to move a ton of freight on a straight track and 3 min. with this machine suffices, usually, to do work that formerly took two men with pinch bars 30 min. to do. Other applications of this spotter include, besides pulling and spotting cars, the moving of materials in lumber yards, steel mills, foundries, in logging work, and on the docks. Many of these manifold uses are made possible, it is averred, through the 360-deg. working radius of the capstan, a feature which permits the reduction of hand labor.

Two sizes, Nos. 1 and 2, are announced by the manufacturer of this unit. The former size has a speed of 40 to 60 ft. per min. while moving one, two or three cars; and the latter size is said to move from three to six cars, at the rate of 26 to 42 ft. per min. The upper bearing of the vertical capstan shaft is especially long, to take the pressure from the rope pull. A cut-steel spur pinion mounted on the motor shaft meshes with a cut, cast-iron spur gear on the worm shaft. The worm is of hardened steel, integral with the shaft, running in roller bearings, and with a ball bearing for taking up the end thrust.

The Caldwell Car Spotter has an automatic oiling system which consists of an upper and a lower reservoir. The spur gear running in the lower reservoir, brings up the oil with it.

The worm gears, running in the lower reservoir, are lubricated by the oil thrown over them by the spur gears, and by the worm dipping into the circulating oil. This also lubricates the radial and thrust bearings on the vertical shaft. Three pet-cocks are provided to regulate the oil level. A grease cup is provided for the upper bearing on the vertical shaft.

Trade Literature
you should know about

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Polyphase Induction Motors—Bulletin 1132 describes the Types AR and ARY polyphase induction motors with cast-steel frames and Timken tapered roller bearings, which are available in ratings from 3 to 200 hp.—Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Floodlighting—Bulletin 216 contains a description and illustrations of the latest type of Golden Glow floodlighting equipment built by this company, with numerous charts and diagrams giving specific performance data.—Electric Service Supplies Co., 17th & Cambria Sts., Philadelphia, Pa.

Portable Electric Tools—Catalog 14 describes the line of Thor portable electric drills and grinders, screwdrivers and drill stands.—Independent Pneumatic Tool Co., 600 W. Jackson Boulevard, Chicago, Ill.

Ball Bearings—Catalog 20 devotes 48 pages to the description, illustration and rating of the various types of radial and thrust ball bearings for a variety of services.—G-A Ball Bearing Mfg. Co., 123-141 N. Albany Ave., Chicago, Ill.

Portable Elevators—A circular describes and illustrates a number of applications of the Revolvator, which is a portable elevator with a revolving platform.—Revolvator Co., 336-352 Garfield Ave., Jersey City, N. J.

Electrical Drives for Power Plant Auxiliaries—Motor Application Circular 7381, under the above title, devotes 24 pages to a discussion of types of motors and control for the various power plant auxiliary services.—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Switchboards and Synchronous Motor Starting Panels—Bulletin 111 illustrates various types of this equipment and describes the eight points of protection claimed for it.—The Ideal Electric & Mfg. Co., Mansfield, Ohio.

Lift Trucks—A group of circulars illustrates and describes the various models and sizes of Plimpton, four-wheel, hand-lift trucks.—The Plimpton Lift Truck Corp., Stamford, Conn.

Recording Units—Bulletin 266 entitled, "Recording Units for Use in the Purchase and Sale of Electricity," contains a number of interesting accounts of how Esterline-Angus instruments have been used to advantage in industrial plants.—The Esterline-Angus Co., Indianapolis, Ind.

Gravity Belt Tightener—A circular describes the Pulmax drive and gives a direct comparison of the operation of the open drive and a standard Pulmax drive for the same installation.—Bird Machine Co., South Walpole, Mass.

Window-Washing Equipment—A circular describes the Cleveland Tramrail window-washing system which consists of a car and trolley supported from a tramrail on the outside of buildings, to facilitate the washing of large window areas. — Cleveland Electric Tramrail Division of The Cleveland Crane & Engineering Co., Wickliffe, Ohio.

Separator Magnets—A folder describes the use of E C & M magnets for removing tramp iron.—The Electric Controller & Mfg. Co., Cleveland, Ohio.

Armature Winding Machines — A number of circulars describe the operation of Chapman armature winding machines of various types and capacities.—P. E. Chapman Electrical Works, St. Louis, Mo.

Lifting Jack—Form 803-C describes the line of Duff lifting jacks which are manufactured in capacities ranging from 1 to 75 tons.—The Duff Mfg. Co., Pittsburgh, Pa.

Galvanized Iron Paint—A circular describes Galvanum, which is a special paint designed for use on galvanized iron surfaces.—Goheen Corporation of N. J., Newark, N. J.

Electric Drills—Special bulletin G-30 describes the improved special ball bearing ½-in. drill with universal motor, and other standard portable electric tools.—The Standard Electric Tool Co., Cincinnati, Ohio.

Flexible Fixture Hangers—Folder 35 and Bulletin 2084 describe the line of Crouse-Hinds flexible fixture hangers and illustrate a number of methods of attachment. — Crouse-Hinds Co., Syracuse, N. Y.

Transformers — Bulletin 2051 describes and illustrates a number of the advantages claimed for the Pittsburgh film radiator for transformers.—Pittsburgh Transformer Co., Pittsburgh, Pa.

Ball-Bearing Motors—A folder describes Marble-Card ball-bearing, a. c. and d. c. motors which are built in ratings up to 75 hp.—Marble-Card Electric Co., Gladstone, Mich.

Bus Supports—A circular illustrates and describes some of the features of the Three-E indoor and outdoor bus supports.—Electrical Engineers Equipment Co., Chicago, Ill.

Manual Controllers—Bulletin 100 describes and illustrates the construction and operation of Clark manual controllers of an improved faceplate type which are built for heavy-duty service.—The Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

Enclosed Switch—Circulars describe the new 40,000 Series Square D enclosed, externally-operated switch which is designed for infrequent operation as in the case of entrance switches, disconnects, and the like.—Square D Co., Detroit, Mich.

Speed Reducing Gears—Catalog 22 covers the Smith line of worm speed-reducing gears on light transmission machinery. These speed reducers are made in ratings up to 5 hp. and the line of light transmission equipment, consisting of pulleys, shafts, bearings, and so on, from 1¼ in. down to ¼ in.—Winfield H. Smith, Springville, Erie Co., N. Y.

Fans—Small circulars describe the line of Peerless, a. c. and d. c., oscillating, non-oscillating, and ceiling fans.—The Peerless Electric Co., Warren, Ohio.

Ball Bearings—A 12-page booklet discusses the results which may be expected from the use of Norma Precision ball bearings in fractional-horsepower motors.—Norma-Hoffman Bearings Corp., Stamford, Conn.

Floodlight—A circular describes the new S-M general-purpose, water-tight, portable floodlight, which may be used either as an emergency light or for constant use under troublesome operating conditions. This unit is adjustable to any position.—Seidler-Miner Co., 316 E. Jefferson Ave., Detroit, Mich.

Speed Reducers—A booklet entitled "Modern Speed Reduction" lists ratings and specifications for the various sizes of worm and herringbone speed-reduction units from fractional horsepower rating up, which are manufactured and stocked in standardized units for immediate delivery.—Boston Gear Works Sales Co., Norfolk Downs, Mass.

Belt User's Book—A 70-page pocket size, handbook under the above title, contains some very interesting information on the installation and maintenance as well as the selection of leather belts.—J. E. Rhoads & Sons, 35 N. 6th St., Philadelphia. Pa.

Non-Metallic Gears—Publication F-4506-B entitled, "Salient Facts on Silent Gears," contains the latest recommendations of the American Gear Manufacturers' Association, including a number of formulas and tables, together with a description of the applications of Micarta gears.—Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

Automatic Self-Starting Induction Motor—Bulletin 110 describes and illustrates the construction and gives the characteristics of the operation of the Type AA, double squirrel-cage, automatic, self-starting induction motors which are built in sizes from 3 hp. to 100 hp.—The Ideal Electric & Mfg. Co., Mansfield, Ohio.

Electric Cranes and Hoists—A 20-page bulletin discusses Shepard equipment for steam and electric railroad shops. Another bulletin discusses the use of this equipment in the leather industry. Both of these are well illustrated.—Shepard Electric Crane & Hoist Co., Montour Falls, N. Y.

Maintenance Equipment Specialties—A circular describes new maintenance equipment specialties such as the Martindale electrical etcher for marking iron and steel articles, soldering transformers, the No. 13 light, portable commutator slotter, and Imperial cleaning liquid and paste.—The Martindale Electric Co., 11710 Detroit Ave., Cleveland, Ohio.

Cutting and Welding Torches—A 12-page catalog describes the various types of Milburn torches for acetylene welding.—The Alexander Milburn Co., Baltimore, Md.

Time Switch—A circular describes the Eureka time switch for automatically switching lights or power on or off.—Eureka Tool & Machine Co., 42 Walnut St., Newark, N. J.